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with his Grandfathers most affectionate
wishes for his best happiness -
Last day of the year 1857
Th. D. Dyke Acland

from the herbarium of
his dear Grandmother)

PART I.

STRUCTURAL AND MORPHOLOGICAL BOTANY.

CLASS BOOK OF BOTANY

BEING

AN INTRODUCTION

TO THE STUDY OF

THE VEGETABLE KINGDOM.

BY J. H. BALFOUR, M.D., F.R.S.E.,
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FELLOW OF THE LINNEAN SOCIETY, ETC.

WITH UPWARDS OF 1000 ILLUSTRATIONS.

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PREFACE.

THE object of the present work is to initiate the student into the study of the structure and forms of the various parts of plants. It embraces what is commonly called Vegetable Organography, or a description of the tissues of which plants are composed, and of the various organs which are concerned in the processes of nutrition and reproduction. Without an accurate knowledge of this department of Botany, it is impossible to make progress either in the physiology or in the classification of plants. It bears to Botany the same relation that anatomy does to practical medicine. It is the basis and foundation on which the superstructure is to be raised.

In the following pages, plants are in the first instance considered with reference to their minute structure. This is the Histological division of the subject, and calls for the use of the microscope. The combinations of the elementary tissues, which constitute the different organs, are next brought under consideration, and the plant is traced from its simplest condition through various morphological changes until it acquires the complete form of the seed-bearing individual. The laws of Morphology, or of the transformations of organs, and the general principles of Vegetable Symmetry, are also brought under the notice of the student. As flowering and flowerless plants differ essentially in their reproductive organs, it has been thought proper to treat of them under separate divisions. The student of Cryptogamic Botany will find in the concluding chapter a general view of the structure and forms of the organs of the lower classes of plants. As it is of great importance that the tyro in Botany should become acquainted with the appearances of plants and of their organs, an extensive series of wood-cuts have been used as illustrations. These have been derived from various sources. The publishers have supplied wood-cuts from Maout's Atlas Élémentaire de Botanique, and from Kitto's Biblical Cyclopædia; other cuts have been derived from original sources as well as from the works of Mirbel, Payer, St. Hilaire, Henslow, Harvey, Greville, and Ralfs. Full explanations of the cuts are given in the notes, and with them are embodied facts relating to Scripture plants, and to other matters not included in the text. At the end of different sections there is inserted a brief recapitulation of what has been stated in regard to particular organs; thus enabling the student to see at a glance the principal points which demand his attention; and in the case of structures requiring further elucidation, references are made to works and papers which may be consulted. In the Histological department of the work there is a description of the microscope and its uses; and lists are given of preparations which may be easily procured for the purpose of illustration. It has not been thought necessary to interrupt the text by introducing the derivation of the various terms, as the author contemplates the publication of a complete glossary for the use of students.

In prosecuting the science of Botany, the student must ever bear in mind that it is only by the examination of plants in the garden and in the fields that he can acquire a thorough knowledge of Organography. No book can make up for the want of this; no descriptions nor illustrations can supply its place. All that the teacher can do by his lectures and text-book is to direct the pupil in his researches, and to refer him to the Book of Nature as the guide in his investigations. The student must not be led away by human authority, however distinguished; his motto must be—

> Nullius addictus jurare in verba magistri.

While he avails himself of all the aid supplied by eminent Botanists, he must endeavour by personal observation to ascertain the correctness of their statements. He must carefully avoid hasty generalization, and a blind attachment to theories, however plausible. His foundation of facts must be solid if his inductions are to be correct. It is by a patient and laborious search after truth, by a diligent and enlightened questioning of Nature, and, above all, by a humble dependence upon Him "who is before all things, and by whom all things consist," that the botanical enquirer can expect to arrive at satisfactory results.

EDINBURGH, *March* 1852.

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CLASS BOOK OF BOTANY.

INTRODUCTORY REMARKS.

1. THE objects presented to us in the material world are naturally divided into two evident groups—the inanimate or unorganised, and the animate or organised. The study of the former, or of inert matter, is peculiarly the province of Chemistry and Mineralogy; while the consideration of the latter, or of living bodies, belongs to the sciences of Botany and Zoology. Geology, in place of being denominated a separate science, may be considered the means by which the sciences of Zoology, Botany, and Mineralogy, are grouped together in one harmonious system.

2. The substances of which the earth is composed, and the living beings which cover its surface, are mutually subservient to each other; and the adaptations which are opened up to the student of natural science, are well fitted to call forth his admiration of the wondrous works of God. The soil, the waters, and the atmosphere, furnish materials for the growth of plants; these, in their turn, afford food to animals; and from these, along with the fruits of the earth, man derives his nourishment. The decay of living bodies contributes to the formation of vegetable mould, and increases the fertility of the soil. Thus there is a complete circle of transformation, in which matter constantly changes place, and undergoes modifications fitting it for the various purposes to which it is applied. There is a oneness in creation which calls upon the student of nature to take a comprehensive view of all.

3. The different kingdoms of nature, and the different departments of science, pass into each other by insensible gradations. A labourer in one field of science cannot say to the labourer in another, I have no need of thee. Like the members of the body, they are knit together to form one harmonious whole, and their individual efforts are all directed to the same great end. The student of inanimate creation, when he examines the composition of the mineral matters of the globe, supplies to the student of living nature information on which to found his researches; and the latter, in his turn, furnishes data by which the former determines epochs in the history of the crust of the globe. By the researches of the chemist, much has been done to promote the pro-

gress of animal and vegetable physiology, and the study of the functions of living beings; and to the labours of the zoologist and botanist the science of geology is indebted for its most important advances. It is therefore necessary that the student of natural history should not confine his attention to mere isolated portions of creation, but should study the harmonies of all parts of it.

4. Those departments of science which have reference to living bodies, and which are hence termed Biological, are in an especial manner related to each other. No one can be considered a scientific anatomist or physiologist, who does not include in his researches a consideration of the structure and functions both of animals and plants. He must study the forms which they present, the cells and vessels which enter into the composition of both, their mode of nutrition, the circulation of their fluids, their various secretions, their reproductive functions, the movements they exhibit, the diseases to which they are liable, and the decay and death which they undergo. It is only by such means that a correct knowledge can be acquired of vital phenomena.

5. While the higher classes of animals and plants are widely separated from each other, the lowest members of each kingdom approximate so closely, that it is scarcely possible to form a line of demarcation. Some bodies, which Ehrenberg represents as animals, are now considered as belonging to the vegetable kingdom; and there are still many living beings whose place in the system of nature has not been fully determined. Mere external form is not sufficient to give distinctive characters, for, in this respect, there are remarkable similarities. Movements will not constitute a diagnostic mark, for these occur in both; and some beings low in the scale have the organic forces of plants, with the locomotion of animals. Even chemical analysis fails to aid the naturalist; for cellulose, long considered as of a vegetable nature, has now been found in the tunics of Ascidians, and a substance, isomeric with starch, has been detected by Gottlieb in some animal tissues.

6. All researches into the limits between animals and plants lead, as Schmidt remarks, to the conclusion, "that from man to the primary animal and vegetable cell, there exists no gap in the realisation of a general idea upon which nature, as a whole, is based. There is no abrupt transition from one kingdom to another, but an insensible gradation. The spore or germ of the *Vaucheria clavata*, one of the Algæ or sea-weeds, with its vibrating filaments (Fig. 1), seems to resemble the young Medusa and the embryonic cell of the swimming Ascidia. The tunic of the Ascidia (Fig. 3) has the substance and structure of a plant, and so also, in all probability, has the umbrella of the Medusa (Fig. 7). Thus

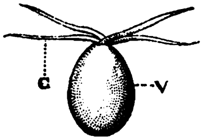


Fig. 1.

Fig. 1. Spore or cellular germ of one of the Algæ (Chætophora); v, vesicle or cell constituting the embryo; c, cilia or moving filaments. From the movements exhibited it has received the name of Zoospore or animal spore.

the embryo-germ of an Alga or sea-weed is identical in elementary composition and form with that of a Medusa or Ascidia; in the former we have the higher stage of development of the plant; in the latter the simpler form of the animal."

7. "Cannot we regard," Schmidt continues, "the Alga as the nurse of its more highly developed embryo? The nurse or the transitionary form of Campanularia exhibits no trace of the phenomena which we necessarily connect with the idea of *animal;* we have here no stomach, no internal cavity for the assimilative process, no spontaneous motion; in short, it is a perfect parent-cell of an Alga. The embryo which, on the bursting of the so-called parent animal, begins to pass through the independent vital cycle, exactly resembles Vaucheria. Like the latter, when the ciliary motion has continued for about two hours, it becomes fixed, and thus attached, is developed into perfect polyps. In the first stage of this process it is a true Alga, in the latter an animal organism. We may regard the Alga as an interrupted formation of the polyp—as a polyp with a simple alternation of generation, whilst Campanularia (Fig. 6) possesses a double one."

8. No chemical or physical difference can therefore be instituted between animals and plants. "Motion is seen in Oscillatoriæ and in the spores of Algæ (Fig. 1), as perfect as in some fixed marine animals. This motion is a necessary fundamental condition of the physical existence of these beings. What the atmosphere is to plants, the ocean is to the adherent marine animals. If the land animals lived in a sea consisting of albumen and hydrate of carbon, they would not require a locomotive apparatus to enable them merely to replenish their formative matter; if the atmosphere contained no carbonic acid, plants would stand in need of locomotion. An internal cavity, for the assimilative process, is to give a great increase of surface to favour the most perfect assimilation. In plants, the whole system of intercellular spaces, and their outlets in stomata or leaf-pores, seems to serve the purpose of an internal cavity. They may be said to combine both the lungs and the intestinal tube. Carbonic acid, the formative material of plants, passes freely through the stomata of the elongated canals of the intercellular spaces, and through the thin-walled cellular extremities of the roots, so as to be taken up into the surrounding cells by diffusion, as formative material; just as albumen and the hydrates of carbon pass through the mouth into the intestinal cavity. As regards respiration, Wöhler has proved that elimination of oxygen takes place in some animals, and it appears that in some fungi carbonic acid is exhaled; and in reference to the substance of the cell-walls, cellulose is found to exist in the cells both of animals and plants. It seems impossible, therefore, in the present state of our knowledge, to give a complete and perfect definition of what is to be considered an animal, in contradistinction to what is to be looked upon as a plant."

9. It is interesting to trace the analogies between the members of the animal and of the vegetable kingdoms, and to observe the wonderful similarity which they exhibit in their various stages of growth and development. The Sertularian polyps (Fig. 2 *a*), with their common stalk bearing numerous individuals (Fig. 2 *b*), each having a certain inherent vital energy, and yet all depending on the general life of the entire compound zoophyte, may be likened to plants producing numerous buds, undergoing certain transformations. A tree may be regarded as a congeries of buds, or separate individuals united on a common stalk. These buds have a certain amount of independent vitality, so that they can be removed and made to grow on other trees by a process of bud-grafting, and yet they are dependent for their continued vigour on the common stem.

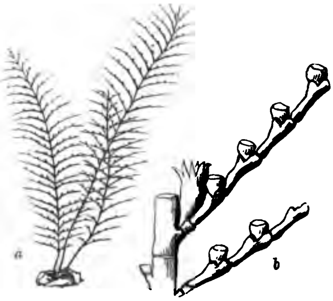


Fig. 2.

10. In some instances, however, leaf-buds are spontaneously detached from plants, as in Bryophyllum calycinum and the bulbiferous lilies, at a certain period of growth, and, on reaching the ground, become at once separate plants. So also, in the case of certain ascidians. Thus in *Clavelina lepadiformis* (Fig. 3) there is a common stalk or

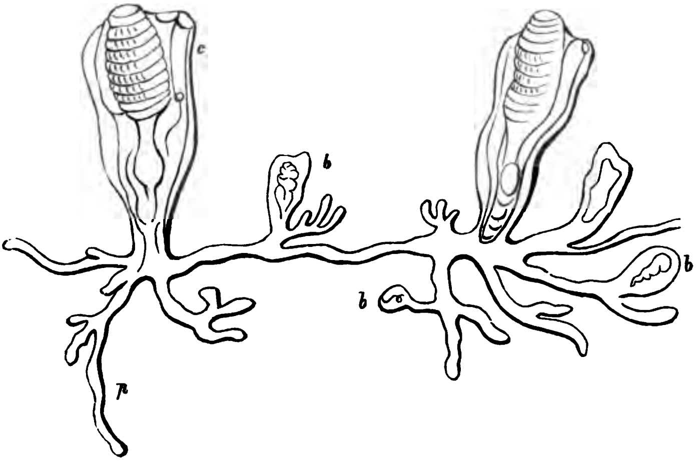


Fig. 3.

Fig. 2. Plumularia pinnata, a compound zoophyte; *a*, natural size of the animal. It may be compared to a tree with numerous living buds; *b*, a portion magnified, showing the separate zoophytes, all of which, except one, have discharged their ova.

Fig. 3. Clavelina lepadiformis, a compound ascidian, with a common stalk like the mycelium or spawn of fungi, and numerous buds *b b b*, in different stages of progress; *c*, the complete animal, capable of living in a detached state.

root-like process, resembling the mycelium or underground stems of mushrooms and other fungi. This stalk gives origin to a series of buds, *b b b*, which are ultimately developed as complete ascidians, *c*. They are then detached as separate individuals.

11. In plants there are two modes in which new individuals are produced, one by the agency of stamens and pistils, or of certain reproductive cells giving rise to seeds or spores containing the embryo plant; the other by the production of leaf-buds, or by the fissiparous division of cells. Animals, in these respects, exhibit resemblances to plants. The most common mode of reproduction in animals is by eggs, equivalent to seeds, depending on the presence of sexes, but the production of buds is by no means rare among some of the lower tribes. Thus, certain medusæ have eggs produced by the agency of testes and ovaries, and at the same time have buds which reproduce the individual. In Figure 4 a representation is given of *Sarsia gemmifera*, a medusa which, besides producing eggs, also exhibits a series of buds attached to a gastric peduncle, *p*. This peduncle, *p*, is highly magnified in Figure 5, and it is seen to end in the mouth at the lower part. Along the sides of the peduncle, buds, *b b*, are developed, and in this state we have a representation of a stalk bearing numerous polyps resembling Campanularia (Fig. 6). These buds, in place of remaining attached under the form of polyps, as in Campanularia, are cast off, swim about, and become Medusæ.

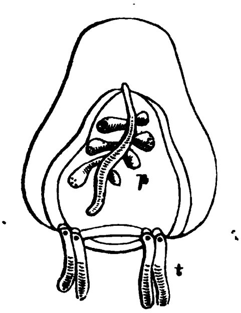


Fig. 4.

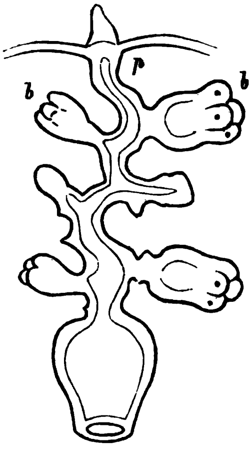


Fig. 5.

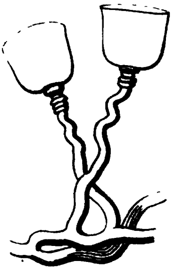


Fig. 6.

Fig. 4. Sarsia gemmifera, one of the naked-eyed medusæ, producing, *p*, a peduncle, with buds, which drop off and become medusæ; *t*, tentacles of the medusa.

Fig. 5. The peduncle, *p*, of Sarsia gemmifera removed, with buds or bulbs, *b b*, which ultimately are detached and become medusæ.

Fig. 6. Campanularia integra magnified. A polyp analagous to that which forms the intermediate state between the egg and the fully developed medusa. The root-like ramifications below resemble the spawn or mycelium of fungi.

12. Analogies may be still farther traced, when we consider the transformations which plants undergo in their various stages of growth, and compare this with the alternations of generation which occur in animals. The seed of a plant, when placed in favourable circumstances, sprouts; a stalk or stem is formed which gives origin to leaf-buds; in due time changes take place, by which flower-buds are formed, and these in their turn form seeds. So it is in the animal kingdom. Polyps and medusæ are, in some instances, different states of the same species. This has been established by the researches of Sars, Dalyell, Steenstrup, and Forbes. The medusa produces eggs which pass through the infusorial state, fix themselves, and become polyps, like Corynæ, Tubulariæ, and Campanulariæ (Fig. 6), and these polyps produce a kind of bud which finally drops off, and becomes a medusa. Thus the egg goes through the intermediate state of a polyp before becoming a medusa. This alternation of generation is similar to the stages of plant-growth, commencing at the seed, and going through the leaf-bud to the flower-bud. Each leaf-bud is an individual as distinct as the polyps in a compound zoophyte. The flower-bud is composed of the same elements as the leaf-bud; but they differ as much as the medusa does from the polyp. The flower-individual arises as a bud from the leaf-individual or the group of leaf-individuals. This is analagous to the buds of Campanularia. The flower-bud, when mature, produces seeds just as the medusa produces eggs. The seed then goes the round of successive or alternating development. "Thus, among plants, leaf-individuals are produced which yield buds becoming flower-individuals, and these, in their turn, produce seeds; in the same way as the animal germ appears as a polyp-bud, and this, on being detached, becomes a medusa, which again produces eggs."

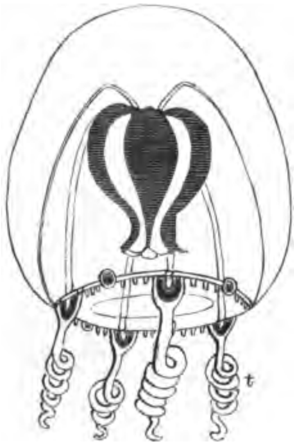


Fig. 7.

13. In tracing the arrangement of the parts of plants and animals, we observe other points of resemblance. Dana remarks, the leaf-bud consists of leaves arranged in a spiral order, and in the polyp some species show tentacles and corresponding parts spiral in development. The same spiral character is seen in the flower, although the volutions, from being closer, appear in a circle. In medusæ (Fig. 7), the regular spheroidal form is more perfectly developed than among the polyps; at the same time, the spiral is seen in their tentacles (Fig. 7, *t*). The

Fig. 7. Modeeria formosa, one of the medusæ, showing the general spheroidal form, and the spiral tentacles, *t*.

only part where analogy seems to fail is, that the medusa bud falls off before its full development, while this is not generally the case in plants. This depends on the difference of nutrition in the two kingdoms of nature. Plant-buds, on separation, usually lose their only means of nutriment; although, as already seen, instances occur where certain buds fall off in an early state, and are capable of independent development.

14. While Botany has thus important bearings on Zoology, it has a still more marked relation to Geology. It enables the geologist to draw conclusions as to the succession of the stratified rocks of the globe, and to determine, in some measure, the nature of the surface and of the climate at different epochs of the earth's history. Professor Phillips remarks, "Geology would never perhaps have escaped from the domain of empiricism and conjecture, but for the innumerable testimonies of elapsed periods and perished creations, which the stratified rocks of the globe present in the remains of ancient plants and animals. So many important questions concerning their nature, circumstances of existence, and mode of inhumation in the rocks, have been suggested by these interesting reliquiæ, and the natural sciences have received so powerful an impulse, and have been directed with such great success to the solution of problems concerning the past history of the earth, that we scarcely feel disposed to dissent from the opinion, that without fossil zoology and botany there would have been no true geology."

15. The stratified rocks of the globe present very distinct floras, and in the examination of them the geologist requires to know thoroughly the microscopic structure of plants, and the arrangement of their cells and vessels. Great service has been rendered to Palæontology in this respect by the beautiful sections of fossil wood first executed by Mr. William Nicol of Edinburgh, whose merits have been too much overlooked of late. Besides the elementary tissues of plants, the geologist must attend to the form of their stems, leaves, and fruit, the scars left by the separation of their different parts, and the minute markings observed on the surface. He must also be fully informed as to the physiological constitution of plants, whether terrestrial or aquatic, their mode of growth, the climates in which they grow, and the nature of the soil in which they flourish. In all these points the labours of the botanist have materially aided the researches of the geologist.

16. There are various marked geological epochs characterised by the predominance of certain great classes of plants. Thus, in the Carboniferous and Permian periods, ferns and their allies prevailed, but associated at the same time with plants higher in the scale; in the periods extending upwards to the Cretaceous epoch, the flora is chiefly characterised by the prevalence of Gymnospermous plants or Dicotyledons with naked seeds, such as Coniferæ and Cycadaceæ; and extending from the chalk to the upper members of the tertiary series, the flora has a greater resemblance to that of the present day in the

predominance of Angiospermous Monocotyledons, and Dicotyledons. Although there is thus a gradation of distinct changes in the flora, still, there is no evidence whatever of any progressive development depending on the transformation of one species into another. There are no grounds for tracing back man to the monkey, or for supposing that, by a gradual series of changes, animals and plants have become more and more perfect and complete. All the facts of science lead to the conclusion, that there are distinct species, which vary within certain limits, and even the alternations of generation already referred to, are evidently circumscribed. The doctrine of transmutation of species is disproved by the best physiological reasonings, and its application to geological phenomena is altogether gratuitous and futile. For a refutation of all such speculative doctrines, and an exposure of their dangerous tendency as regards the cause of truth, we refer to Hugh Miller's Footprints of the Creator, Whewell on the Indications of the Creator, and Sedgwick on the Studies of the University of Cambridge.

17. In its relation to Medicine, Botany must be viewed not only as furnishing the medical man with valuable information in regard to the affinities and properties of plants, so as to enable him to substitute one for another, with certainty in circumstances, when the usual remedies are not at hand; but it must be regarded as an important branch of preliminary study training his mind to habits of observation and diagnosis, which are so essential to the successful prosecution of his profession. The physiology of plants, too, enables him to study in a simple form many of those phenomena which are complicated and obscure in the higher order of living bodies. A complete literary and scientific education tends in no small degree to enhance the attainments of the accomplished physician. "It is of importance that a class of men so widely diffused, and mingling so much with society as the members of the medical profession, should be so instructed as to give a tone to conversation, and to promote among those with whom they associate the love and the pursuit of literary and scientific accomplishments."

18. The science of botany includes everything relating to the vegetable kingdom, whether in a living or in a fossil state. Its object is not, as some have supposed, merely to name and arrange the vegetable productions of the globe. It embraces a consideration of the external forms of plants—of their anatomical structure, however minute—of the functions which they perform—of their arrangement and classification—of their distribution over the globe at the present and at former epochs, and of the uses to which they are subservient. It examines the plant in its earliest state of development, when it appears as a simple cell, and follows it through all its stages of progress until it attains maturity. It takes a comprehensive view of all the plants which cover the earth, from the minutest lichen or moss, only visible by the aid of the microscope, to the most gigantic productions of the tropics. It marks the relations which subsist between all members of the vegetable world, and traces

the mode in which the most despised weeds contribute to the growth of the mighty denizens of the forest. It is a science, then, which demands careful and minute investigations—requires great powers of observation and research, and is well fitted to train the mental powers to vigorous and prompt action.

19. Botany may be divided into the following departments:—1. *Structural* Botany, having reference to the anatomical structure of the various parts of plants, including vegetable Histology, or the microscopic examination of tissues: 2. *Morphological* Botany, or the study of the form of plants and their organs; these two departments are often included under the general term of Organography. 3. *Physiological* Botany, by some termed Organology, or the study of the life of the entire plant and its organs, or the consideration of the functions of the living plant. 4. *Taxological* Botany, or the arrangement and classification of plants. 5. *Geographical* Botany, the consideration of the mode in which plants are distributed over the different quarters of the globe. 6. *Palæontological* Botany, the study of the forms and structures of the plants found in a fossil state in the various strata of which the earth is composed.

PART I.

STRUCTURAL AND MORPHOLOGICAL BOTANY.

20. This department includes a consideration of the minute structure of the various parts of plants, and of the forms which they assume. In prosecuting it the student may either consider analytically the anatomy of each part of the plant at the same time that he examines its form, or he may, in the first place, consider those structures, which enter generally into the composition of every part of the plant, and then study synthetically the mode in which they are grouped together in the different organs. The latter is the method which has been usually adopted, and seems, upon the whole, that which is best fitted for the purposes of the student.

CHAPTER I.

VEGETABLE HISTOLOGY, OR THE STUDY OF THE ELEMENTARY STRUCTURE OF PLANTS.

21. The elementary tissues of plants are few and simple. They consist of organs to which the names of *cells* and *vessels* are given. The former are minute bladders or vesicles (Fig. 8), varying in size and form, which, when united together, constitute *Cellular tissue* (Fig. 9); while the latter are closed tubes of an elongated form, frequently tapering to each end (Fig. 10), and, when combined, constituting *Vascular tissue.* The distinction between cells and vessels is founded on their comparative length. Occasionally, however, cells become lengthened, as in the case of some hairs, and the filamentous or thread-

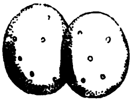


Fig. 8.

Fig. 8. Two cells or vesicles taken from the Elder (magnified).

like tissue of Fungi (Fig. 11), so as not to differ from vessels as regards length. Such long cells are distinguished chiefly by the thinness and delicateness of their texture.

22. On making a transverse section of a succulent stalk, such as that of Rhubarb, or of a cucumber or melon, we perceive, by the aid of a glass, circumscribed angular meshes and rounded openings; and, in a longitudinal section of the same stalk, similar meshes are also seen with long tubes of various kinds. The angular spaces are cells such as those seen in Figure 12, and the tubes having rounded openings (Fig. 12) are vessels. The membrane forming the walls of both cells and vessels is composed of a substance called *Cellulose*, in many respects resembling starch, but differing in giving a yellow in place of a blue colour, with iodine. The membrane has in general no visible

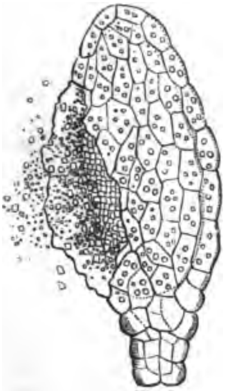


Fig. 9.

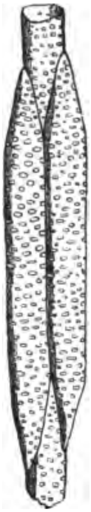


Fig. 10.

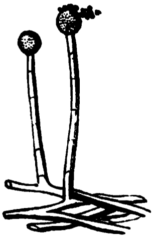


Fig. 11.

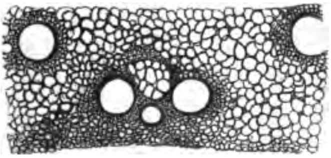


Fig. 12.

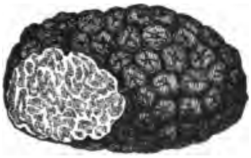


Fig. 13.

Fig. 9. Cellular tissue from Liverwort, a cellular plant (magnified).

Fig. 10. Spindle-shaped vessels, or closed tubes united, and forming vascular tissue (magnified).

Fig. 11. Mould fungus, composed of cells, those at the root being long and tube-like (magnified).

Fig. 12 Section of a bamboo, after a specimen cut by Mr. W. Nicol, showing angular meshes of cells and rounded openings of vessels (magnified).

Fig. 13. Truffle (*Tuber cibarium*) a subterranean fungus, consisting entirely of cellular tissue.

pores or perforations; but fluid matters pass through it easily. Some plants, such as truffles (Fig. 13), mould (Fig. 11), Liverworts (Figs. 14 and 15), and Lichens, consist of cellular tissue alone, and hence are called Cellular plants; while others, such as ordinary flowering plants, consist of cells and vessels combined (Fig. 12), and receive the name of Vascular plants.

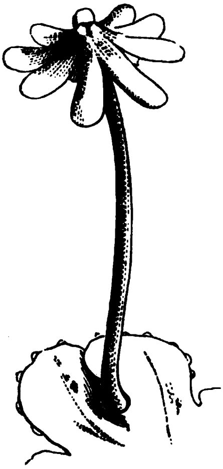


Fig. 14.

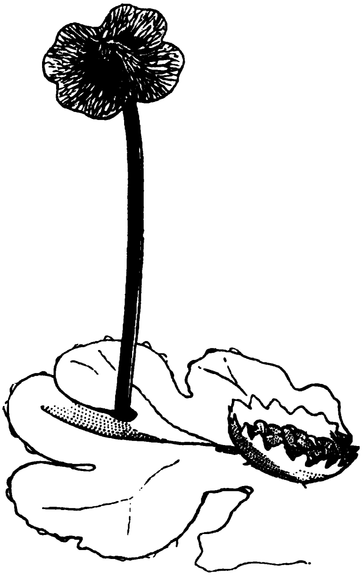


Fig. 15.

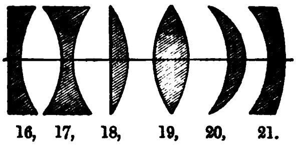
I. ON THE USE OF THE MICROSCOPE IN THE EXAMINATION OF VEGETABLE TISSUES.

23. The study of the minute tissues of plants is denominated Vegetable Histology. In prosecuting it, the student must have recourse to the microscope, an instrument of great value, both to the anatomist and physiologist, and which it seems to be proper, in the first instance, to describe. In carrying on histological examinations, it must be borne in mind that it is not enough to possess a good

Figs. 14 and 15. Liverwort (*Marchantia polymorpha*), a cellular plant, showing its various kinds of fructification, which will be afterwards noticed.

microscope; there must also be the power of using it properly. Constant practice is required in order to be able to do so, and hence the value of a regular course of instruction in histology. In ordinary botanical dissections, it is seldom necessary to use a very high magnifying power; it is chiefly when examining some of the points connected with the formation of the embryo and the motions of fluids that such aid is required.

24. *Lenses.*—The ordinary lenses in use are the *double convex* (Fig. 19), with two convex faces; *plano-convex* (Fig. 18), with one convex and one flat-face; *meniscus* (Fig. 20), with a convex and concave face, and a sharp edge, the concave face having the larger radius; *concavo-convex* (Fig. 21), with a concave and convex face of equal radius, the edge being flat; *plano-concave* (Fig. 16), with a flat and concave face, and *double concave* (Fig. 17), with two concave faces. The first three (Figs. 18, 19, 20) are called sharp-edged or convex lenses, and cause parallel rays to converge, or to come to a focus; the last three (Figs. 16, 17, 21) are called flat-edged or concave lenses, and cause divergence. By a combination of convex and concave lenses, certain advantages are obtained which will be afterwards noticed. The focus of a lens is the point to which the rays converge. The magnifying power of a lens is estimated by its focal length, or the distance of the focus from its centre. The focal distance of the eye varies from 6 to 12 inches, and hence 10 is taken as the mean. This number is a convenient one, for, by adding a cypher to the denominator of the fraction expressing the focal length of a lens, we give its magnifying power. Thus, a lens whose focal length is $\frac{1}{4}$ of an inch, is said to magnify 40 times.



Figs. 16-21. Different kinds of lenses—16. Plano-concave. 17. Double concave. 18. Plano-convex. 19. Double convex. 20. Meniscus. 21. Concavo-convex. 18, 19, 20, are sharp-edged lenses, and cause convergence. 16, 17, 21, are flat-edged, and cause divergence.

25. *Simple Microscope.*—The most useful instrument for a botanical student is the simple microscope, in which the object is viewed directly through a lens, so arranged as to be capable of being adjusted, by means of a screw, to its exact focal distance, and of being moved over different parts of the object. The single lenses used may be either a double convex or a plano-convex. When higher powers are wanted, a *doublet* may be employed, consisting of two plano-convex lenses of different focal lengths, viz., one to three, placed at a certain distance from each other, with a stop between them to limit the aperture; or a Coddington or periscopic lens, consisting of two hemispherical lenses, cemented together by their plane faces, having a stop between them, or rather having a groove in the whole sphere filled with opaque matter. In the simple microscope, single or combined lenses may be used, varying in focal lengths from $\frac{1}{4}$ to $1\frac{1}{2}$ inch.

26. In ordinary lenses, such as those described, there are sources

of confusion both from their form and from the nature of the glass of which they are made. These two causes give rise to what are termed *aberrations* of *sphericity* and *refrangibility*. The former, called also *spherical aberration*, depends on the circumstance of a convex lens, or one with a spherical surface, not bringing all the rays exactly into one focus; while the latter, denominated also *chromatic* (coloured) *aberration*, depends on the different refractions of the rays in passing through glass, which thus causes the objects to be coloured. In the human eye the variable curvature of the lens is with the view of correcting aberration, while its variable density seems to alter the figure of it under pressure. When using low magnifying powers these aberrations do not materially interfere with the accuracy of the observation, and this may be remedied to a certain degree by means of a *diaphragm* or *stop*, which diminishes the aperture, and, consequently, the pencil of light, by stopping the rays passing through the margins of the lens. Although, in such a case, however, the pencil of light may not suffer much distortion, yet it is often too small to shew the markings which we wish to see. There is a want of *definition*, as it is termed, in consequence of the moderate light not bearing dispersion over the magnified picture. In more minute observations, however, especially with the compound microscope, it is essential to have lenses which are free from all sources of confusion, and which combine a large aperture with definition. Hence the value of achromatic lenses (Fig. 22, *a*), composed of a double convex lens of plate or crown-glass, and a plano-concave of flint-glass (Fig. 22, *b*). The combination of these different forms of lenses, constructed of materials having different dispersive powers, is found to remedy the defects attributable to aberration. In the achromatic glass, the two kinds of lenses are accurately fitted together, and united by Canada balsam. In the finest compound microscopes, all the glasses are achromatic, and several are combined in one piece.

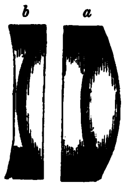


Fig. 22.

27. *Compound Microscope.*—The compound microscope is constructed on a different principle from the simple one. In using it, the observer does not view the object directly, but a picture or image of the object is formed by one lens or set of lenses, and that image is seen through another lens. The lens next the object is called the *object-glass* or *objective;* that next the observer is the *eye-piece* or *ocular*. The object-glass is generally made of two or three achromatic lenses fixed in a tube, as seen at *o*, in Figure 24, while the eye-piece consists of two plano-convex lenses (Fig. 24, E and C), with their flat-faces next the eye, and separated at half the distance of the sums of their focal lengths, with a diaphragm between them (Fig. 24, B).

28. In Figure 23, a representation is given of one of Smith and Beck's microscopes, for students. A is the brass stand, supported firmly on three feet, and having two upright flat cheeks, to the top of which

Fig. 22. *a*, An achromatic or aplanatic lens, consisting of a double convex lens of plate-glass, and a plano-concave of flint-glass. *b*, Section of the plano-concave lens.

the stage-plate, *d*, is fixed. Into the stage-plate is screwed an upright round tube, to which is attached an open tube, *g*, in which the body of the instrument, *f h*, slides. By moving the body up and down in this tube, the coarse adjustment is effected, and when the instrument is brought near to the object on the stage-plate, *d*, a finer adjustment is made by means of the screw with the milled head, *e*, which either raises or depresses the part by which *g* is attached to the upright tube. The mirror is represented at *b*, supported on trunnions, and capable of motion upwards or downwards, so as to reflect the light on the object placed on the stage-plate; *c* is the diaphragm or stop, or perforated plate attached to the stage, with the view of shutting off the extreme rays of light. The object-glass or objective is placed at the lower end of the instrument, *f*, and the eye-piece or ocular, at the upper part, *h*.

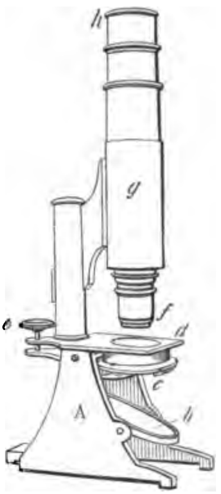


Fig. 23.

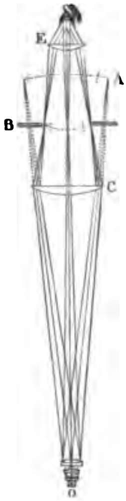


Fig. 24.

29. In Figure 24 a diagram is given to explain the mode in which the compound microscope acts. In this figure, *o* is the object, above which is seen the triple achromatic object-glass or objective, consisting of three achromatic lenses, which are combined in one tube; E C is the eye-piece or ocular, consisting of two plano-convex lenses, one at E, being the eye-glass, and the other at C, the field-glass. Three rays of light are represented as proceeding from the centre of the object, and three from each end of it. These rays have a tendency to proceed so as to form an image of the object at A, but coming in contact with the field-glass C, they are made to converge and meet at B, where the diaphragm is placed to intercept all light except what is necessary for the formation of a perfect image. The image formed at B is viewed as an original object by the observer through the eye-glass E.

30. The magnifying power of the compound microscope depends on the sum of the magnifying powers of the object-glass and the eye-

Fig. 23. Smith and Beck's compound microscope for students. A, brass stand, supported on three feet; *b*, mirror supported on trunnions; *c*, diaphragm; *d*, stage-plate on which the object is placed; *e* screw with milled head for fine adjustment; *g*, brass tube in which the body of the instrument is moved, so as to effect the coarse adjustment; *f*, the object-glass, or objective; *h*, the eye-piece or ocular.

Fig. 24. Diagram to shew the mode in which the compound microscope acts. O, an object, with three rays of light from its centre, and three from each of its ends; E C, eye-piece, consisting of two plano-convex lenses—one at E, the eye-glass, the other at C, the field-glass; B, diaphragm; A, the point where an image would be formed if the rays were not made to converge by the lens C.

piece; and its power may be increased or diminished by a change in either, or both of these glasses. It is better, however, to increase the power by a change of the object-glass than by altering the eye-piece. In the instruments made by Ross, the following are the effects produced by different combinations of eye-pieces A, B, C, and object-glasses of different focal lengths, the magnifying power being estimated in lineal measure, or by diameters, as it is called :—

EYE-PIECES.	OBJECT-GLASSES.					
	2 Inches.	1 Inch.	½ Inch.	¼ Inch.	⅛ Inch.	$\frac{1}{12}$ Inch.
A	20	60	100	220	420	750
B	30	80	150	350	670	950
C	40	100	200	470	870	1200

31. In the compound microscope there are mechanical parts which are connected with the general form and appearance, and there are optical parts which determine its value as an instrument for histological researches. In the mechanical arrangements, it is of importance to have steadiness, easy means of adjustment, and facility for making observations; while, as regards the optical parts, a flat field of vision, clearness of definition, and complete achromatism, are of the highest consequence. A magnifying power of 200 or 250 diameters or linear, is sufficient for examining ordinary vegetable structures. The object-glasses may vary from 1¼ to ¼ of an inch in focal lengths.

32. In measuring minute objects, an instrument called a *Micrometer* is used. The ordinary stage-micrometer consists of a piece of glass ruled at intervals of $\frac{1}{100}$ of a millimetre, or about $\frac{1}{2500}$ of an inch apart. On this the object to be measured is placed, so that both it and the lines may be visible at the same time under the microscope. This, however, cannot always be accomplished easily, more especially under high magnifying powers. The eye-piece micrometer consists of a scale ruled on glass, and inserted in the diaphragm of the ordinary eye-piece of the compound microscope. With this instrument, when using a magnifying power of 500 or 600 diameters, we can estimate spaces of $\frac{1}{5000}$ to $\frac{1}{7500}$ of an inch with tolerable precision. The cobweb screw-micrometer, constructed of fine wires or cobwebs, which are made to separate from each other by means of a delicate screw, is employed for minute observation, but it is very apt to become deranged by the effects of friction causing the screw to wear unequally. In observations of extreme delicacy, Welcker's micrometer has been lately recommended as the best. It surpasses the cobweb screw-micrometer in elegance of principle and in cheapness.*

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* A full description of it is given by Dr. Robertson in the Edinburgh Monthly Journal of Medical Science for April 1851.

33. In making drawings of microscopic objects, a *Camera lucida* is useful, in which, by means of a prism and a metallic speculum, the representation of the magnified object is thrown upon paper. In testing the power of an instrument, certain objects are used, in which peculiar markings occur, which can only be properly seen by a fine instrument. Either artificial or natural objects may be chosen as test-objects. The former have been prepared by Robert, a Konigsberg optician, and consist of glass plates, on which are ruled, with a diamond, systems of a hundred lines, which, 10 by 10, approach closer together and are finer, according to a definite standard. With most instruments only the 6th and 7th systems can be distinctly made out to be composed of separate lines. Superior instruments reach the 8th and 9th. No instrument has yet reached the 10th system, with its component lines. The best test-objects are the natural ones, as being regular and uniform in their markings, such as the scales of Podura or Lepisma. The cross striæ of Hipparchia Janira, a very common brown butterfly, can only be seen distinctly by the best instruments.

34. Vegetable structures, when examined by the microscope, may be viewed either by transmitted light, as transparent objects, or by reflected light, as opaque objects. In the former case, they are put on slides of thin plate glass, three inches by one, some water is added, they are then covered with very thin pieces of crown or plate glass, and the light is thrown on them by the mirror below the stage. Examinations of tissues are best made during the day, with the light reflected from a white cloud. When observations are made at night, a sperm-oil lamp is used, and the light is transmitted to the mirror through a plano-convex lens, called a condenser. To correct the unpleasant glare attendant on the reflected light from an ordinary mirror, Mr. Handford makes a mirror of thin concave-glass, three inches in diameter, the back rendered white by plaster of Paris. This is mounted on brass, and fitted over the frame of the ordinary silvered mirror, thus not requiring the latter to be removed. The advantage is, that the whole rays reflected from the surface of plaster of Paris are brought into one focus, together with those reflected from the surface of the glass, and thus an equal and brilliant light is produced. In viewing opaque objects, the light is thrown by the condenser directly on the object, and sometimes a metallic speculum, called a *Lieberkuhn*, is connected with the object-glass, by means of which an additional supply of light is obtained.

35. When mounting or putting up vegetable preparations for permanent use, the objects are preserved either in alcohol or a weak solution of creasote, and the thin glass is cemented over them by black japan varnish. For preserving microscopic objects, as mosses, Dr. C. Müller takes clear talc, splits it into thin layers, and cuts it into oblong pieces of proper size. Then, with a penknife, he splits one of these pieces (from one of the narrow sides) *half-way through*, so that it may be opened to admit the object, and then close by its elasticity, the unsplit end serving as a holder. A drop of water is introduced

into the slit with the object; when laid aside it dries, and may be again rendered fit for use by dipping in water. This does for mosses, but it will not answer for minute structure, which spoils on drying.

36. Schleiden gives the following method of preserving minute structures for the microscope. Upon a glass slide of the common form, two narrow slips of paper are gummed, of a thickness proportioned to the object, and at a distance which is regulated by its size. Between these the object is laid in a drop of solution of chloride of calcium (one dram to half an ounce of water). A thin slip of glass, sufficient to cover the object and paper-slips, is put on; the slips are gummed, and the thin glass applied to its place, where it is retained by the gum drying. The whole may be secured by pasting a long slip of paper over all, with a hole for the object. The advantage of this method is preventing *running in.* Chloride of calcium being deliquescent, never dries up, and, if evaporation takes place, water is easily introduced at the open sides of the thin glass. The points to be attended to are—1, that the paper between the glasses be thick enough to prevent much pressure on the object, and not so thick as to allow it to float about or fall out at the side; 2, that the drop of solution be not too large, but covering the object, and yet not reaching the paper. Glycerine may be used in place of chloride of calcium in cases where the objects are very delicate, or contain chlorophyll or albumen.*

II. CELLS AND CELLULAR TISSUE.

37. Cellular tissue is generally called *Parenchyma*, and it also receives the names of Areolar, Utricular, and Vesicular tissue. It exists more or less in all plants, and abounds in fleshy roots, stems, and leaves, and in succulent fruits. It constitutes the pith and outer bark of trees, and the central part of rushes, of the Papyrus (Figs. 25 and 26) and of the Rice-paper plant. By cultivation, the turnip, carrot, cabbage, and other esculent vegetables, acquire much cellular tissue, and become tender and succulent. The bladders or cells (Fig. 40, p. 21), of which the tissue is composed, vary in size. In a cubic inch of a leaf of the Carnation, there are said to be upwards of three millions of cells. They are frequently seen $\frac{1}{1000}$, $\frac{1}{500}$, and $\frac{1}{300}$ of an inch in diameter. In some of the Cucumber tribe, and in the pith of aquatic plants, large cells, $\frac{1}{50}$ and $\frac{1}{30}$ of an inch in diameter, occur.

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* For a complete account of the various kinds of microscopes, and their use in histology, see "Practical Treatise on the Use of the Microscope, by John Quekett;" also Ross's article Microscope in the Penny Cyclopædia; and Schacht, Das Microscop. Berlin, 1831.

38. Cells are either surrounded by a simple thin membrane, or by thickened walls. The thickening of the walls of cells takes place by a deposit of woody matter on the inside, as seen in the microscopic structure of the hard shell of the Coco nut and Piaçaba fruit, in the stone of the peach and cherry, and in the seed of the Ivory and Date palms. Occasionally, rounded portions of the cell-wall are left uncovered by deposits, giving rise to the formation of *Porous*, or *Dotted*, or *Pitted* cells (Figs. 27 and 41); while, at other times, the thickening matter assumes the form of a ring or of a spiral coil, thus constituting *Annular* (Fig. 28) and *Spiral* cells (Fig. 29). In Vaucheria, Chætophora (Fig. 30), and other sea-weeds, peculiar reproductive cells called spores are met with, having thread-like filaments surrounding them, which exhibit a vibratile motion resembling that of the cilia of animal mucous membranes. Some of these ciliated spores are represented in Figures 31, 32, 33, and also in Figure 1, p. 2. In Equisetum or horse-tail (Fig. 34), there are reproductive cells, which are surrounded by two filaments, with thickened clavate or club-shaped extremities (Figs. 35, 36), which are remarkably hygrometric, and exhibit movements when breathed upon. In Figure 35, the filaments are coiled round the cell; in Figure 36, they are expanded.

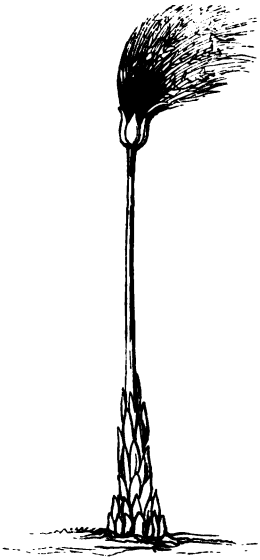


Fig. 25.

39. When formed of cells composed of a homogeneous or uniform membrane, the tissue is called *Membranous* cellular tissue; when of spiral cells it is denominated *Fibrous* cellular tissue, or *Inenchyma* (from a Greek word signifying fibres, with the general termination *enchyma*, applied to tissue). Elongated cells or tubes, with pointed extremities (Fig. 45, p. 23), when united together, form the tissue called *Prosenchyma*. The membranous walls of some elongated cells occasionally unrol in a spiral manner. Quekett has noticed this in hairs taken from the fruit of Cycas revoluta (Fig. 37). Spiral cellular tissue exists in many Orchids (Fig. 38), as Stelis, Oncidium, and Pleurothallis; also in the outer covering of the seed of Collomia linearis, and of the fruit of Salvia verbenaca wild clary. The spiral cells in the last two mentioned cases, when placed in water under the microscope, exhibit interesting movements, owing to the solid spiral fibre rupturing the softened membrane of the cell, and expanding in all directions. In some of these cases, the spiral coils are

Fig. 25. Papyrus antiquorum, found in the Nile. Its stem contains much cellular tissue. In the figure the plant is shewn before flowering, with numerous scales at the base.

of a gelatinous consistence, and lie loose in the cells. In Liverworts (Figs. 14, 15, p. 12) and other cellular plants, spiral fibres, called *Elaters*, are found in spindle-shaped cells (Fig. 39).

40. Cells differ in form according to the mode in which they are aggregated. They are frequently rounded or spherical (Fig. 40); at other times they present angular (Fig. 41) or elongated (Fig. 42) forms, such as pentagonal or five-angled, hexagonal or six-angled, prismatic, square, fusiform or spindle-like. When the cells are so placed as to touch each other on every side, the Parenchyma is called *complete*. This is seen in the dodecahedral or twelve-sided, and prismatic Parenchyma of pith, and in the flat tabular Parenchyma of the outer corky bark of trees. When the individual cells touch each

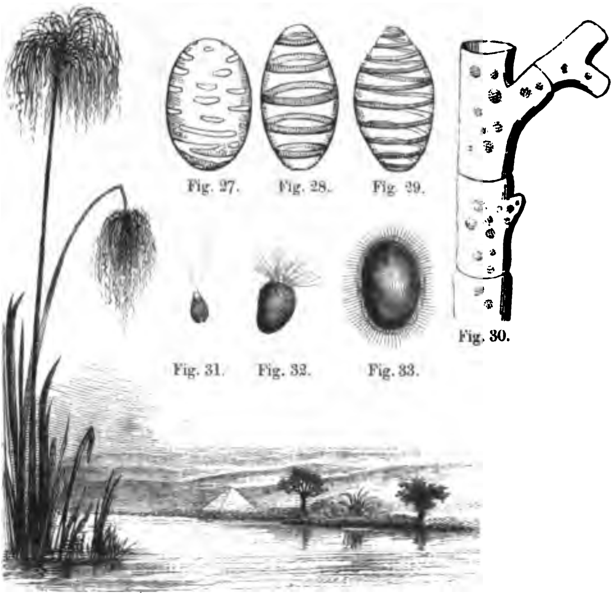


Fig. 27. Fig. 28. Fig. 29.

Fig. 30.

Fig. 31. Fig. 32. Fig. 33.

Fig. 26.

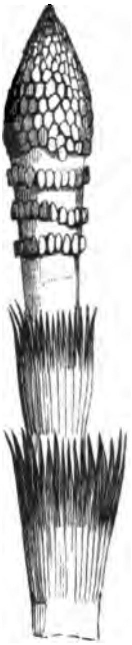


Fig. 34.

Fig. 26. Papyrus antiquorum, with clusters of flowers hanging down. The plant was used in ancient times to furnish paper. It is the Bulrush of the Bible, and is called in Hebrew Gome.

Fig. 27. Porous or pitted, and reticulated cell from the mistleto.

Fig. 28. Annular or ringed cell from the mistleto. The fibre inside is in the form of a complete ring.

Fig. 29. Spiral cell, or cell with a spiral fibre inside, from an orchid.

Fig. 30. Chætophora, one of the algæ. A cellular plant composed of cylindrical cells, containing granules.

Fig. 31. Small cell or spore, with two vibratile filaments.

Fig. 32. Spore with numerous cilia at one end.

Fig. 33. Spore with numerous cilia surrounding it.

Fig. 34. Equisetum Telmateia, one of the species of horse-tail. It has much silica in its composition, and the fructification, with hygrometric cells, is at the apex.

other only at certain points, the Parenchyma is *incomplete*. This occurs in the case of the spherical and elliptical cells (*merenchyma*) of succulent plants, such as the Cactus (Fig. 43), and in the *stellate* or star-like cells of the rush, Callitriche verna and Bean (Fig. 44). In incomplete Parenchyma spaces are left between the cells, which are either large circumscribed cavities called *lacunæ* (Fig. 44), or continuous passages called *intercellular canals*. The spaces between the

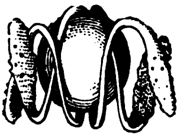


Fig. 35.

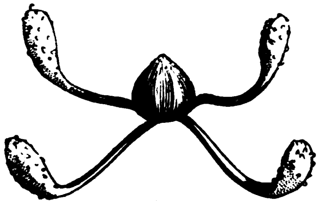
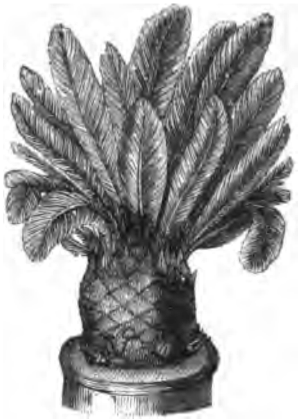


Fig. 36.



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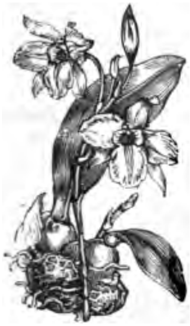

Fig. 38.

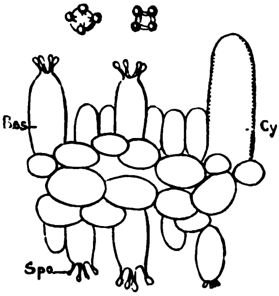

Fig. 40.

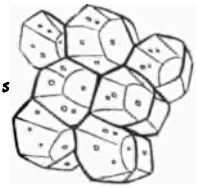

Fig. 41.

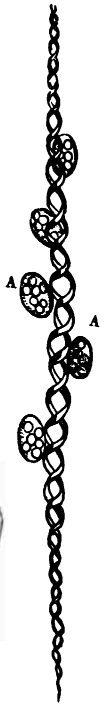

Fig. 39.

Fig. 35. Spore of Equisetum in the moist state, with two filaments coiled round it. Each filament has two club-shaped extremities.

Fig. 36. The same spore or cell in the dry state, with the filaments uncoiled.

Fig. 37. Cycas revoluta (¶ 39), a plant yielding a substance like sago. It has naked seeds.

Fig. 38. An orchid (*Maxillaria*) of warm climates, containing spiral cells in its composition.

Fig. 39. Elaters, or spiral fibres, with spores or reproductive cells A A, from liverwort (*Marchantia*). The fibres are elastic, and serve to scatter the spores.

Fig. 40. Cells of the mushroom, loose and more or less oval or elliptical in form, with cavities between some of them. The letters refer to the different forms of reproductive cells, to be afterwards noticed; and the spores are represented above the figure.

Fig. 41. Hexagonal cellular tissue from pith of Elder. The cells are dodecahedral and dotted.

cells are filled either with fluids of different kinds, or with air. Occasionally the intercellular substance assumes a thickened or corky consistence, and unites the cells firmly; and it appears to be sometimes prolonged over the surface of the plant in the form of a cuticular covering.*

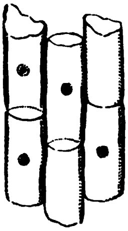

Fig. 42.

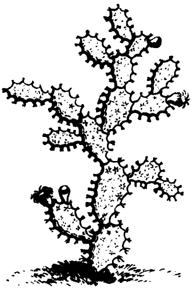

Fig. 43.

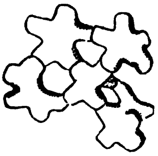

Fig. 44.

III. VESSELS AND VASCULAR TISSUE.

41. The vessels of plants which collectively form vascular tissue, may be considered as differing from cells chiefly in their length. They are closed tubes tapering to each extremity. Their walls are composed of the chemical matter called cellulose in a membranous form, and they are thickened and altered in various ways by the formation of deposits in their interior.

42. *Woody Tissue.*—This is composed of thickened tubes or elongated cells, with conical extremities overlapping each other, as seen in Figure 45. The tubes are said to be fusiform or spindle-shaped, and the tissue has received the name of *Pleurenchyma*, from a Greek word meaning a rib, on account of the support which it furnishes to the stems and leaves of plants. The woody portion of trees and shrubs, and of all the ordinary flowering plants, consists in part of this tissue. It exists also in the inner bark, and in the veins of the leaves. The materials used for ropes and cordage, linen, certain Indian muslins, mummy cloth, and mats, consist of the woody fibre of plants from which the more delicate tissues have been removed by maceration in

Fig. 42. Elongated cylindrical cells of the lily. Several of them contain a nucleus or cytoblast.
Fig. 43. Opuntia vulgaris, one of the succulent plants belonging to the Cactus tribe.
Fig. 44. Stellate or star-like cells of the Bean, with lacunæ or intercellular spaces.

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* Mohl, sur la Connexion des Cellules des Plantes. Ann. des Sc. Nat. 2d ser. viii. 304.

water. Flax or lint is thus procured from the bark of Linum usitatissimum (Fig. 46), hemp from Cannabis sativa (Fig. 47), New Zealand flax from Phormium tenax (Fig. 48), Pita flax called in Sicily Zambarone from Agave Americana, Sun-hemp from Hibiscus cannabinus, and bass or bast from the common Lime or Linden-tree. Fibres are also procured for manufacture from the Pine-apple plant (Ananassa sativa), from Yucca gloriosa (Fig. 49), from Boehmeria nivea, which yields the Chinese grass fibre, from most of the plants belonging to the mallow and nettle tribes, and from some of the leguminous plants, such as Crotalaria juncea, which supplies a kind of Bengal hemp.*

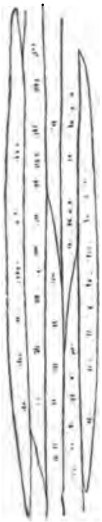
Fig. 45.

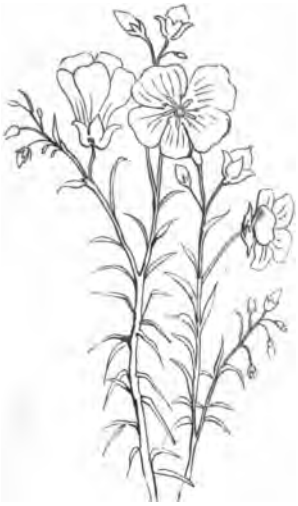
Fig. 46.

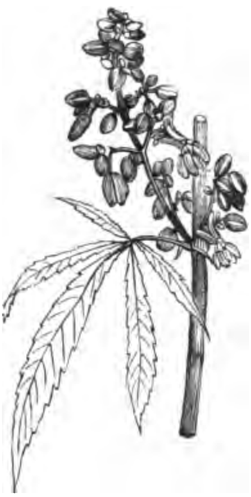
Fig. 47.

43. The tenacity of different kinds of woody fibres, as contrasted with silk, is given in the following table, by De Candolle :—

Silk supported a weight of . . .	34
New Zealand Flax, ...	$23\frac{1}{5}$
Common Hemp, ...	$16\frac{1}{3}$
Common Flax, ...	$11\frac{3}{4}$
Pita Flax, ...	7

44. If the maceration of the fibre is carried to a great extent, a pulp is formed from which paper is manufactured. In ordinary paper the

Fig. 45. Woody tissue or pleurenchyma, consisting of fusiform or spindle-shaped tubes overlapping each other. Sometimes the term prosenchyma is applied.

Fig. 46. Linum usitatissimum, the Flax plant, called in Hebrew, Pishtah, and in Greek, Linon.

Fig. 47. Cannabis sativa, the Hemp plant. Staminiferous or male flower.

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* Specimens of these, and of many other kinds of vegetable fibres, are deposited in the Museum of the Edinburgh Botanic Garden. In particular, two beautiful specimens of Chinese grass-cloth, made from Boehmeria nivea, have been presented by Dr. Cleghorn.

vegetable structure is destroyed, but in rice-paper, which is not prepared by maceration, it is preserved. This can be easily seen on examination with the microscope. By a similar mode of examination the texture of articles made from vegetable tissues may be ascertained.

45. Pleurenchyma does not occur in cellular plants, such as Mosses, Lichens (Fig. 50), Liverworts (Figs. 14, 15, p. 12), Seaweeds, Mushrooms and other fungi (Figs. 11 and 13, p. 11). The tissues of these plants speedily disappear under the action of water, and hence, perhaps, the reason of their rarity in a fossil state. In the very young state woody tubes are delicate, and it is only in proportion as they attain maturity that their walls acquire a thick consistence. This depends on the formation of layers of cellulose, which have received the name of lignin or sclerogen. In the sap-wood of ordinary trees the woody tubes are thickened in their walls, but are pervious; while in the heart-wood they are rendered solid by the deposited matter, which is often variously coloured. Some of the fully formed woody tubes, when cut across, exhibit distinct zones or circles of ligneous deposit. The diameter of the woody tubes varies from $\frac{1}{2000}$ to $\frac{1}{200}$ of an inch.

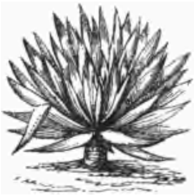

Fig. 48.

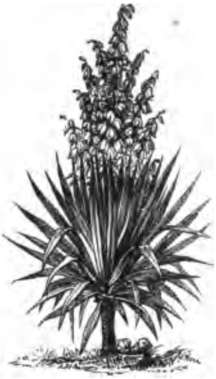

Fig. 49.

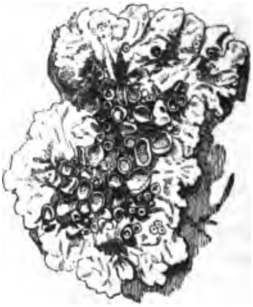

Fig. 50.

46. *Punctated or Disc-bearing Woody Tissue.*—This kind of woody fibre or pleurenchyma is seen in firs (Fig. 51) and other cone-bearing trees, when a section is made in the direction of the rays running from the centre to the circumference of the stem. It is sometimes called glandular woody tissue. The fibres exhibit under the microscope discs or large circular dots, which are saucer-like spaces or depressions on the walls of the tubes. They are seen in Figure 52. When two woody tubes lie together face to face, the depressions or hollowed-out spaces on each of them are applied like two watch glasses leaving lenticular cavities, which are sometimes filled with air. When viewed

Fig. 48. Phormium tenax, New Zealand Flax plant, which yields very tenacious fibres.
Fig. 49. Yucca gloriosa, Adam's needle, a Liliaceous plant which yields fibres.
Fig. 50. Lichen (*Parmelia*) with rounded spots of fructification containing minute germs.

by transmitted light under the microscope, these appear like circular discs. The dot seen in the centre of the disc depends on a portion of the wall being thinner than the rest. In Figure 53 this structure is seen in a magnified form. The walls of the fibres or tubes are marked *p f*, the internal cavity of the fibre *c f*, and the lenticular cavities *c l* formed between the two contiguous fibres, *r m* being one of the cellular

Fig. 51.

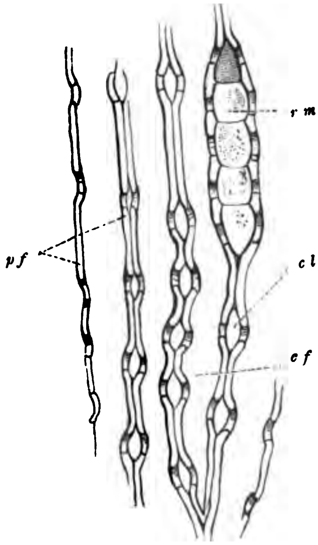

Fig. 53.

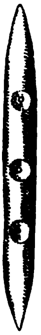

Fig. 52.

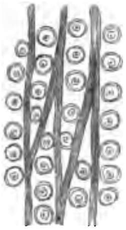

Fig. 54.

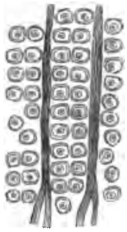

Fig. 55.

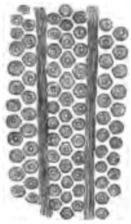

Fig. 57.

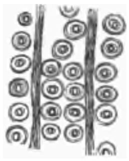

Fig. 56.

Fig. 51. Pinus sylvestris, common Scotch fir. Like other Coniferæ or Cone-bearers, it has punctated woody tissue in its stem and branches, and scarcely any porous vessels.

Fig. 52. Punctated or disc-bearing woody fibre of the fir.

Fig. 53. Vertical section of part of the stem of a fir, to shew the formation of the discs. *p f* marks the walls of the same fibre or woody tube. *c f* is the cavity of a woody tube. *c l* one of the lenticular cavities formed by two contiguous tubes. These cavities appear as discs by transmitted light. *r m* medullary ray, consisting of cellular tissue proceeding from the centre to the circumference.

Fig. 54. Disc-bearing woody tubes of the pine. Single rows of discs on each tube (after Nicol).

Fig. 55. Disc-bearing woody tubes of the pine, with a double row of discs on each fibre (after Nicol).

Fig. 56. Section of vessels of Pinus Strobus, Weymouth pine, showing a double row of discs, each row consisting of discs at the same level, or opposite to each other (after Nicol).

Fig. 57. Section of woody tubes of Araucaria, shewing double and triple rows of discs, which are alternate with each other (after Nicol).

rays proceeding from the centre to the circumference, interposed between the walls of two contiguous fibres. In the case of some fossil woods, pieces of silica like double-convex lenses have been removed from the cavities. The discs are in single, double, or triple rows (Figs. 54–57). When there is more than one row, the individual discs in the rows are either at the same level, that is, opposite to each other (Figs. 55, 56), as in the case of ordinary pines (Fig. 51), or they are at different levels, that is, alternate with each other (Fig. 57, 58), as in Araucarias and Altingias (Fig. 59). Mr. William Nicol, than whom no one has devoted more attention to the structure of wood, was the first to apply these characters to the determination of fossil woods. Sometimes spiral fibres are seen between the discs. Woody tissue with discs, but without the central dot, occurs in many plants, as in Wintera aromatica (Fig. 60), the plant which yields Winter's bark, Illicium floridanum, and in some other trees.

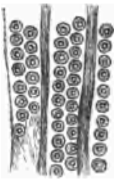
Fig. 58.

Fig. 60.

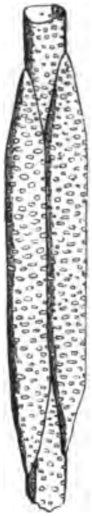
Fig. 61.

Fig. 59.

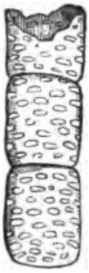
Fig. 62.

Fig. 58. Sections of woody tubes of Altingia excelsa, shewing double rows of discs which are alternate, each disc being at a different level from that next to it.

Fig. 59. Altingia excelsa, Norfolk Island pine (after Hugh Miller), from a specimen transplanted during summer into the open ground of the Edinburgh Botanic Garden.

Fig. 60. Wintera aromatica, Winter's bark tree, which exhibits punctated woody tissue.

Fig. 61. Dotted or pitted vessels united, so as to form Bothrenchyma or Taphrenchyma, or, in other words, pitted tissue.

Fig. 62. Dotted or pitted, or porous vessel taken from the melon. It is formed originally of pitted cells united, the divisions being seen externally, and giving the vessel a moniliform or necklace-like appearance.

47. *Dotted or Pitted Vascular Tissue.*—The vessels, or, as they are often called, Ducts, forming this tissue, are usually continuous tubes of a larger size than the other vessels of plants (Fig. 61), and presenting often broad or oblique extremities in place of pointed ones like other vessels. Their dotted or pitted appearance, as seen in Figures 61 and 62, depends on the mode in which the encrusting matter or cellulose is formed inside. In place of being deposited equally over the whole surface of the membrane, as in ordinary woody fibre, it leaves rounded uncovered spots at various intervals, and these, when viewed by transmitted light, appear from their thinness to be perforations or holes. Hence, the name *Porous*, which is often applied to these vessels. In old dotted ducts it is occasionally found, that the thin membrane of the dots or pits has been absorbed, and actual perforations have taken place. Dotted vessels frequently exhibit contractions at intervals, giving rise to a jointed or bead-like appearance. In such cases, as in Figure 62, they are seen to be formed of dotted cells placed end to end, with the partitions between them obliterated, so as to form continuous cylindrical and sometimes branched tubes. In the Elm and Lime the dotted ducts have sometimes spiral fibres ramifying between the dots.* The membranous walls of dotted vessels sometimes unrol in a spiral manner. Dotted ducts are found in large quantity in the wood of trees, and they constitute the large rounded openings which are seen in the transverse section of the stems of oak, poplar, willow, &c. They also abound in the bamboo, (as seen in Figure 12, p. 11, where the porous vessels are distinguished by their large round apertures), and in other plants of rapid growth. The names of *Bothrenchyma* and *Taphrenchyma*, given to this tissue, are derived from Greek words signifying pits.

48. *Spiral vessels* form the tissue called *Trachenchyma*, on account of its resemblance to the tracheæ or air-tubes of animals. They are tubes tapering to each extremity, and having their membranous walls strengthened by the formation of elastic spiral fibres within (Fig. 63). They vary from $\frac{1}{3000}$ to $\frac{1}{300}$ of an inch in diameter. When lying together the vessels overlap each other at their extremities (Fig. 63), and occasionally, by the absorption of the membrane, perforations of their walls take place, so as to establish a communication between two contiguous tubes. The fibres are usually rounded and simple; but sometimes two or more are combined, as seen in one of the vessels in Figure 63, so as to form a flat band. These flat ribbands, consisting of fibres which vary in number from 2 to 25, or more, are

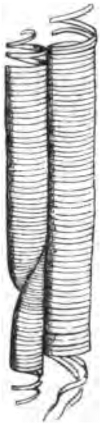

Fig. 63.

Fig. 63. Spiral vessels taken from the melon, shewing the elastic fibres uncoiled, and the vessels overlapping at their pointed extremities. These vessels form the tissue called Trachenchyma. The general name of Angienchyma being given to all kinds of vascular tissue.

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* Mohl, sur la Structure des Vaisseaux Ponctués. Linnæa, 1842, p. 1. Ann. des Sciences Nat. 2d ser. t. xviii. p. 321.

met with frequently in the stems of Bananas (Fig. 64) and Plantains, and in the shoots of Asparagus. The spirals in such cases are called compound. The spiral fibres have such tenacity, that when the vessels are ruptured they can be pulled out and separated from the inside of the membrane. This capability of being unrolled characterises the fibre of true spiral vessels. On breaking the young shoots or leaf-stalks of the Geranium, Strawberry, and Rose, or the leaves of the Hyacinth, Amaryllis, and Banana, and pulling the parts gently asunder, the fibres can be easily seen in the form of a fine cobweb. When the aerial stems of the Banana (Fig. 64) and Plantain are cut across, the spiral fibres may be pulled out in large quantity so as to be used for tinder. The fibres of Musa textilis, a kind of Plantain, are used in manufacture. The coils or volutions of the fibre are said to be in general left-handed. In the garden lettuce vessels are met with, some having the fibre turning to the left, others to the right. In the scarlet bean the coils of the fibres are left-handed, while the plant itself turns to the right in twining. Spiral vessels are abundant in young plants and shoots, while in the hard stems of trees and shrubs they chiefly surround the pith.

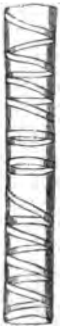
Fig. 65.

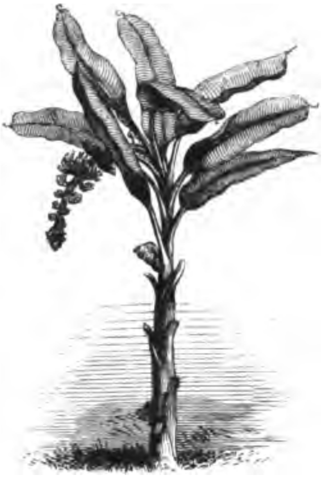
Fig. 64.

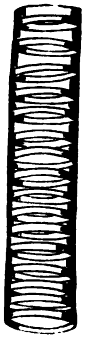
Fig. 66.

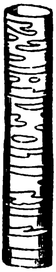
Fig. 67.

Fig. 64. Aerial stem of Banana (*Musa sapientum*), formed by sheathing leaves. The proper stem is subterranean, and the stem shewn in the figure is a shoot sent up, bearing leaves and fruit, and then decaying, to give place to another shoot. The cluster of fruit is seen at the top. The extremity of the cluster is abortive; the flowers at the base of the stalk bearing fruit. The plant contains numerous spiral vessels, some of them having flat ribbands composed of numerous fibres combined. Such vessels being called Pleiotracheæ.

Fig. 65. Vessel partly spiral and partly annular, taken from the melon plant. In the middle of the vessel a complete fibrous ring is seen, while the fibre at the ends is spiral. The ring is formed by a breaking up of the spiral coil.

Fig. 66. An annular vessel taken from the melon plant. The rings of fibre are complete.

Fig. 67. Vessel partly annular and partly reticulated, taken from the melon plant. Some complete rings are seen, while others are broken up and divided, so as to form dots and reticulations. The dots are in this case opaque, and thus differ from pits in porous vessels.

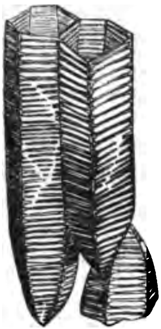

Fig. 68.

49. *Modifications of Spiral Vessels.*—The spiral vessel is the type of what is called the *fibro-vascular* tissue, or that tissue which is composed of vessels having membranous walls strengthened by fibres of some sort. In their perfect condition the vessels have a complete spiral or cork-screw-like coil inside, which is elastic, and can be unrolled. In different plants, however, and in different parts of the same plant, the spiral vessel undergoes certain modifications and changes. Sometimes, as in ferns, the spiral fibre becomes united to the membrane, so that it cannot be unrolled. This constitutes what is called the *closed* spiral. At other times the fibre is broken up into rings, reticulations, bars, or dots. These changes take place in the progress of growth, and their various stages may be traced in the vessels of such plants as the garden balsam or melon. In Figures 65, 66, 67, are seen the transformations effected in vessels. Thus, in Figure 65, there is a complete spiral fibre, which in the middle of the vessels is interrupted by the formation of a fibrous ring; in Figure 66, the fibrous rings are uniform throughout, while, in Figure 67, some of the rings are complete, and others are broken up into lines or dots. *Annular* vessels are those in which the fibre is in the form of rings (Fig. 66). These rings in Mammillaria quadrispina, and in some other plants of the Cactus tribe (Fig. 43, p. 22), are very deep, and leave only a small hole in the centre of the vessel. Annular vessels are from $\frac{1}{800}$ to $\frac{1}{400}$ of an inch in diameter. *Reticulated* vessels have interlacing fibres on the membrane, as seen in Figure 67, while in *Scalariform* vessels (Fig. 68), the fibre is so broken up as to appear in the form of bars or lines like the steps of a ladder, whence their name. The entire walls of some scalariform vessels are capable of being unrolled in a spiral manner. In Ferns (Fig. 69), we meet with scalariform vessels which assume a prismatic form. In place of lines, the fibre is in some instances so broken up as to appear in the form of dots or opaque points. The appearance of bars, dots, and reticulations, may sometimes be traced not to a thickening of the membrane by means of fibres, but to an actual thinning of the membrane, such as has been already noticed in the case of dotted ducts.

Fig. 69.

50. *Laticiferous Vessels.*—These vessels, as seen in Figures 70, 71, consist of long branching tubes or passages, having a diameter of about $\frac{1}{1400}$ of an inch, forming, by their union, an anastomosis or net-work, like the veins of animals. They receive their name from containing

Fig. 68. Scalariform or ladder-like vessels of tree ferns. The fibre is in the form of bars or lines; and the vessel is prismatic.

Fig. 69. Athyrium Filix-fœmina, a British fern. Ferns contain scalariform vessels in their composition.

a fluid called *Latex*, of a granular nature, often milky or coloured, and well seen in the India-rubber and Gutta Percha plants, the Mudar plant, the Cow-tree (Fig. 72) Spurges, Dandelion, Lettuce, Chicory, and Celandine. Many of these fluids contain a large quantity of caoutchouc; some of them are bland and nutritious, as that of the Cow-tree; others are narcotic and acrid. The Latex exhibits movements which have given origin to the name *Cinenchyma*, or moving tissue, applied to Laticiferous vessels by some authors. The motions have been particularly described by Schultz,* and will be afterwards considered under Physiology. When fully formed, the vessels of latex exhibit in their course contractions and dilatations of an irregular kind. They are considered by some as composed of cells placed end to end, with their partitions more or less completely absorbed; while others consider them as intercellular passages lined with a membrane. These vessels are found especially in the bark and leaves of plants.

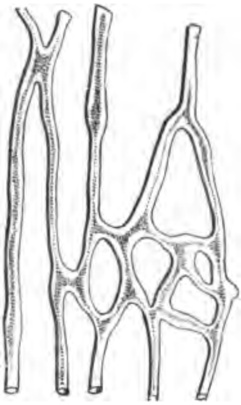
Fig. 70.

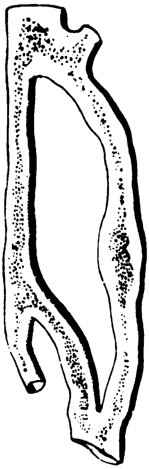
Fig. 71.

Fig. 72.

Fig. 70. Laticiferous vessels or Cinenchyma from the dandelion. The vessels contain granules.

Fig. 71. Laticiferous vessels, containing orange-coloured granular latex from the Celandine (*Chelidonium majus*).

Fig. 72. Cow-tree of the Caraccas (*Galactodendron utile*). It yields a bland milky fluid which is contained in laticiferous vessels.

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* Schultz's paper is in the 18th vol. of the Nova Acta Academiæ. Cæsar. Leopold.-Carol. Naturæ Curiosorum. See also Ann. des Sc. Nat. 2d ser. t. vii. p. 257.

IV. CONTENTS OF THE VEGETABLE TISSUES.

51. It is not proposed at this place to give a full account of the substances which are found in the tissues of plants, but simply to notice a few of the more evident contents of cells and vessels, or those which the student is likely to observe in his examination of structure. The details as to the organic and inorganic constituents of plants, and the mode in which they contribute to the nutrition of plants, will be given under Physiology. Some substances are found generally in the cells and vessels of all plants, while others are very limited in their distribution. To the former class belong cellulose, lignin, starch, gum, sugar, oils, colouring matter, and certain nitrogenous and saline compounds; to the latter belong alkaloids and certain special secretions.

52. *Cellulose* is an essential part of the structure of cells and vessels. It is in many respects allied to starch, and is changed into starch by the unaided action of heat, or by sulphuric acid, or caustic potash. When iodine is applied to it, it becomes yellow, and if sulphuric acid is added, a blue colour, like that of iodide of starch, is produced.* Cellulose was long considered as peculiar to vegetable tissues, but it has been recently detected by Schmidt,† Löwig, and Kölliker, in the tunics of ascidia and other molluscous animals. The thickening of the cellular membrane is accomplished by the deposition of layers of encrusting matter, to which the name of *Sclerogen* or *Lignin* has been given. This substance may be looked upon as a modification of cellulose. It is frequently seen in the form of distinct concentric layers, which vary in their composition in different circumstances. The hard cells in the stone of the peach, and in the shells of other fruits and seeds, consist of cellulose, with deposits of lignin. So also woody fibre, the encrusting matter of which varies in hardness and colour in different trees and shrubs. The spiral threads, rings, and bars, in the membrane of cells and vessels, consist apparently of two layers, one being cellulose, the other woody matter. Cork is a nitrogenous substance, which, next to cellulose, according to Mitscherlich,‡ is the most important constituent of the cell-wall. It occurs in a marked degree in the outer bark-cells of many trees, and it is also found in other plants, such as in potatoes. In the latter the cork-cells do not contain starch, and they are thus distinguished, as well as by chemical properties, from the cells made up of cellulose. Cellulose, corky substance, and fatty matters, seem to be found in the same cell; and when the

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* For a full account of the chemical nature of cellulose and other substances entering into the composition of elementary tissues, see Mulder's Chemistry of Organic Bodies, translated by Fromberg, 347-493. For the nature of the cell-walls, see Mohl on the Structure of the Vegetable Cell, in Taylor's Scientific Memoirs, vol. iv. p. 91. Mohl on Cellulose, Bot. Zeitung, 1847. Ann. des Science Nat. 3 serie, Botanique, tom. viii. p. 240. Also Grundzuge der Anat. de Veg. Zelle, 1851. Schulze states that a mixture of a solution of chloride of zinc and iodide of potassium colours cellulose blue.

† Taylor's Scientific Memoirs, vol. v. p. 1.

‡ See Reports of the Berlin Academy for March 1850, p. 102. Ann. der Chem. und Pharm. tom. lxxv. p. 305.

cellulose has been absorbed, the corky substance alone remains. It forms the outermost part of the cell-wall, and unites the cells together.

53. *Starch* is one of the substances found in great abundance in the cells of plants where it is stored for the purposes of nutrition.* It is not found in animal tissues, although a substance isomeric with it is stated to have been detected in them by Gottlieb. A distinguishing character of starch is the blue colour which it assumes on the addition of iodine. It occurs in fine grains, more or less oval or rounded, which vary in diameter from the 4000th to the 240th of an inch. The individual grains either lie distinct from each other in the cells, as in the potato, wheat, and peas (Fig. 73), or they are aggregated so as to form compound grains, as in West Indian Arrow-root, and Portland Sago procured from Arum maculatum. Grains of starch frequently present at one end a spot called the hilum, which is seen in the grains given in Figure 73. It is a concavity or nucleus over which successive layers have been deposited, giving rise to the striated appearance seen in potato starch. Starch is accumulated in the internal, and often in the subterranean parts of plants. It occurs abundantly in fleshy roots, and in stems, as well as in seeds and fruits, and is easily separated by washing. The ordinary cultivated grains yield starch in considerable quantity, so also the Potato, Arrow-root and Cassava plants, the Sago-palms, and Banana fruit (Fig. 74). That procured from the Arrow-root plant (Maranta arundinacea), consists of dull white grains, while that from the potato, and from various species of Canna supplying tous-les-mois, is in the form of large shining particles. Sago and Tapioca are granulated forms of starch, the former being procured from the cells of various species of Sagus and Metroxylon, the latter from the Cassava plant. The existence of starch in the bark and young wood of trees, such as the Birch and Pine, render them useful as articles of food in cold countries. Lichenin is a form of starch existing in the cells of Iceland moss (Fig. 75), and

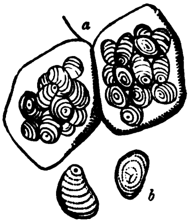

Fig. 73.

Fig. 74.

Fig. 75.

Fig. 73. *a* Starch cells of the pea, showing grains of starch in the interior. *b* Separate starch grains, with striæ and hilum.

Fig. 74. Cluster of Bananas. The fruit contains much starch.

Fig. 75. Iceland moss (*Cetraria islandica*), a cellular plant, yielding Lichenin, a kind of starch.

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* Starch is composed chemically of Carbon and the elements of water (Hydrogen and Oxygen), its formula being $C^{12} H^{10} O^{10}$. See remarks on starch, by Payen, in Ann. des Sciences Nat. Partie Bot. 1838, p. 5.

other lichens; while Inuline is the starchy matter supplied by the roots of the Dahlia, Dandelion, and Elecampane. By the action of prolonged heat, as well as by the addition of diluted sulphuric acid, and of malt, starch is converted into a soluble gummy substance called dextrin. The same change we shall find occurs during germination or the sprouting of the seed.

54. *Gum* is another substance contained in vegetable tissues. When pure, it is clear, soluble in water, and also in dilute acids, but not soluble in alcohol or ether. It is one of the forms through which vegetable matter passes in being applied to the purposes of plant life. It exists largely in the vegetable juices. From the bark of many trees it is procured in the form of an exudation. Two well marked kinds of gum are met with: Arabine, soluble in cold water, constituting the chief ingredient of gum-arabic, procured from various species of Acacia (Fig. 76); and Cerasine, insoluble in cold water, and readily soluble in boiling water, constituting the gummy secretion obtained from the cherry and plum. A substance, called Bassorin, or vegetable jelly, is found in Tragacanth, the roots of some Orchids (Fig. 77), as well as in Carrageen (Sphærococcus crispus), and other sea-weeds. It is allied to gum, but differs in swelling up and becoming gelatinous when mixed with water. Another jelly-like substance called Pectic acid exists in the juice of turnip, beet, and carrot, as well as in the apple and pear.

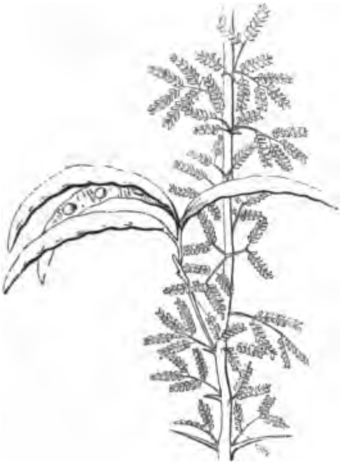
Fig. 76.

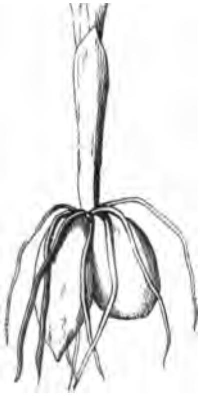
Fig. 77.

Fig. 78.

Fig. 76. Acacia Seyal, one of the trees yielding gum-arabic, $C^{12} H^{11} O^{11}$. It is the Shittah tree and Shittim wood of the Bible.—Exod. xxv. 5; xxxv. 7, 24. Isaiah xli. 19.

Fig. 77. Roots of an orchis, which supply bassorin, a kind of gum. The salep of the Turks is procured from them.

Fig. 78. Saccharum officinarum, the sugar-cane, a grass which contains much saccharine matter in its cells and vessels. The sugar it furnishes is called cane sugar, $C^{12} H^{11} O^{11}$. The stalk of the sugar-cane is called a culm.

55. *Sugar* occurs abundantly in the sap of plants. When pure, and in a solid state, this substance is crystalline, and soluble in water. It occurs, however, in an uncrystallisable form. There are two marked varieties of it. Cane sugar, procured from the sugar-cane (Fig. 78), sugar-maple, beet, carrot, and many other plants; and grape-sugar,* occurring in numerous fruits, as grapes, gooseberries, currants, peaches, and apricots. During the sprouting of the seed, starch is converted into grape-sugar, and a similar change is induced by the action of malt, and of any ferment. A sweet substance (not a true-sugar), called Mannite, is procured from the Manna-ash, as well as from various sea-weeds, from species of Eucalyptus, and from the Dandelion.

56. The substances which have been noticed as occurring in the elementary tissues are important as organic products concerned in the growth and nourishment of plants, and they will call for special consideration when we treat of the functions of the living vegetable. Some differences of opinion exist among chemists as to their exact atomic composition; it is sufficient at present to notice that they all consist of a definite proportion of carbon, united to oxygen and hydrogen, the elements of water. They are convertible into each other by the action of heat, and of various chemical re-agents, and by the powers of vegetation. The ultimate composition of several of them is identical, and the difference of their properties, in such instances, seems to depend on differences in the arrangement of their atoms.

57. Another class of substances, found in the tissues of plants, and essential for the process of vegetation, consist of carbon and the elements of water, with the addition of nitrogen or azote. Hence, they are called nitrogenous or azotised. They occur abundantly in the gluten of wheat flour. Schleiden includes them under the general name of vegetable mucus. The chief substances which enter into the composition of this nitrogenous matter are albumen, fibrine, caseine, legumine, and emulsine.

58. *Nuclei.*—The cells of plants, at some period of their existence, usually contain what are denominated nuclei or cytoblasts. The nucleus is a small rounded body resembling a minute cellule, which is either loose or attached to the walls of the cell containing it. It is seen in Figure 42, p. 22. It frequently contains smaller bodies called nucleoli. The nucleus has an important function to perform in cell growth, as will be noticed under cytogenesis or cell-development, and after a certain period it frequently disappears.

59. *Chlorophyll and Colouring Matters.*—Chlorophyll or Phytochlor, is the matter which gives the green colour to plants. It is a coloured fatty or wax-like substance, which may be separated by the action of alcohol and ether. The green colour is associated with globules of various sizes, which are either free or united together. The globules of chlorophyll can be seen under the microscope in any of the green parts of plants. In delicate structures, such as the cellular tissue of

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* The formula for Dry Grape-sugar is $C^{12} H^{12} O^{12}$.

mosses and liverworts, they are easily examined.* The colour is only produced under the action of light; hence chlorophyll exists in the superficial cells of the parenchyma, thus differing from starch, which is produced in the internal and subterranean organs, whence light is excluded. It undergoes changes according to its state of oxidation; hence the tints which the green leaves acquire in autumn. There would appear, therefore, to be a colourless chlorophyll present in plants, which is acted on by light, oxygen, and other agents, so as to give rise to green, yellow, and red tints. Schleiden says, the yellow leaves in autumn contain proportionately more wax than the green leaves of summer, the yellow rind of the ripe fruits more than the green rind of unripe fruits. The tints of flowers depend either on variously-coloured insoluble globules, which are considered to be of a nitrogenous nature, or on soluble substances which have not been fully examined. Colouring matters not green are included under the name of Chromule.

60. *Oily, Fatty, and Resinous Matters.*—These are contained in cells and in special canals and cavities, called receptacles of secretion. The oils are either fixed or volatile; the former being divided into drying, fatty, and solid; while the latter are distinguished according as they consist of carbon and hydrogen alone, or of these elements combined with oxygen or with sulphur. Resinous matter occurs either in the form of fluid balsams, or of the various kinds of solid resin and pitch. In the rind of the orange and lemon, receptacles of oil occur. These are represented in Figure 79, which is a vertical section of part of the rind of the orange, the reservoirs of volatile oil being marked R R R. The cellular tissue of the rind is seen surrounding the oil cavities, and the cells are elongated and condensed, so as to form a compact tissue in the walls. Turpentine canals are met with in the bark of Pines; and Vittæ or oil-canals, in the fruit of umbelliferous plants, such as the Coriander (Fig. 80). In the fleshy covering of the fruit of the Olive (Fig. 81), there are numerous oil-cells. The fruit of the Guinea-palm (Fig. 82), yields a solid oil called Palm oil. The dotted appearance of the leaves of the orange, myrtle, Eucalyptus, and St. John's wort, depends on the presence of numerous cells or cavities containing essential oil.

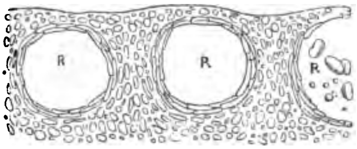

Fig. 79.

Fig. 79. Vertical section of part of the rind of the orange, showing receptacles of volatile oil, R R R surrounded by cells.

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* Green vesicles or granules allied to chlorophyll, are found in the parenchyma of the body of Hydra viridis, of many Turbellarias (Hypostomum viride, and Typhloplana viridata), and Infusoria (Euglena viridis, Stentor polymorphus, Bursaria vernalis, Loxodes Bursaria). What has been called the red eye in many infusoria, by Ehrenberg, is considered by Nægeli as an altered state of the chlorophyll, which is converted into a red oil. In many unicellular algæ, as Protococcus nivalis, Pleurococcus miniatus, and Palmella miniata, the chlorophyll disappears completely, and is converted into a red or orange oil. Nægeli, Gattungen einzelliger Algen physiol. und systemat. bearbeit. Zurich, 1849. Also Siebold, Observations sur les plantes et les animaux unicellulaires. Ann. des Sciences Naturelles, 3 serie, Botan. t. xii. p. 138.—For remarks on Chlorophyll, see Mohl's paper 'Sur la Chlorophylle.' Ann. des Sc. Nat. 2d ser. Bot. ix. 150.

61. As allied to these secretions, we may notice *Caoutchouc*, which is found in the milky juice of plants, especially those belonging to the Fig, Spurge, and Dogbane orders. The trees most prolific in this substance are, Siphonia Caoutchouc, Urceola elastica, and Ficus elastica. Of these, the first extends over a vast district in central America; and the caoutchouc obtained from this tree is best adapted for manufactures. Over more than 10,000 square miles in Assam the Ficus elastica is abundant. The Urceola elastica (which produces the Gumtowan of the Malays) abounds in the islands of the Indian Archipelago. It is described as a creeper of so rapid growth, that in five years it extends 200 feet, and is from 20 to 30 inches in girth. This tree can, without being injured, yield, by tapping, from 50 lbs. to 60 lbs. of caoutchouc in one season. A curious contrast is exhibited in the tardy growth of the tree from which gutta percha is obtained, and which requires from 80 to 120 years to attain maturity. Gutta percha is the produce of a sapotaceous plant (Isonandra gutta). *Wax* is also found in the tissues of plants, and it frequently occurs as a secretion on the stems, as in the Wax Palm (Fig. 83), and on the surface of fruits, as in the bloom or glaucous secretion of the plum and the candleberry myrtle.

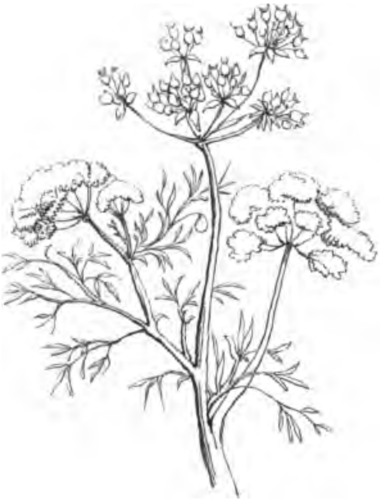

Fig. 80.

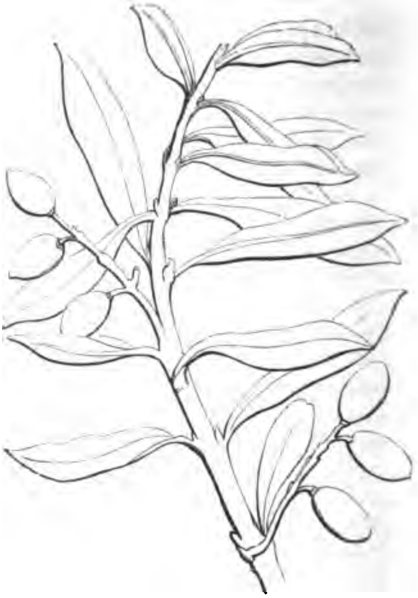

Fig. 81.

62. *Air-Cavities.*—Cells and intercellular spaces containing air are found in many aquatic and marsh plants, apparently with the view of

Fig. 80. The Coriander plant (*Coriandrum sativum*), the fruit of which exhibits vittæ, or cavities containing volatile oil. It is the Gad of Scripture (Exod. xvi. 31; Num. xi. 7).

Fig. 81. The Olive tree (*Olea europea*), the fruit of which yields a fixed oil by expression. It is the Zait or Sait of the Scriptures (Gen. viii. 11; 1 Kings vi. 23, &c.)

rendering them buoyant (Fig. 84, V). In some cases they are regular in their formation, being surrounded by cells which are built up on a uniform plan in each species of plant, as in Pondweeds (Fig. 85, *l*). In other instances they are formed by the destruction or absorption of part of the cellular tissue, as in the case of many hollow stems. The air-cells in Limnocharis Plumieri, are beautiful objects under the microscope.

63. *Raphides* or *Crystals.*—Cells and vessels also contain various mineral and organic acids, combined with alkaline substances. The most important of these acids and alkalis will be noticed when considering the chemistry of vegetation, and the products furnished by different natural orders. At present we shall consider the composition of certain crystalline matters found in cells, to which the name of Raphides has been given. These are present in greater or less quantity in almost all plants. They consist of oxalic, phosphoric, malic, sulphuric, and carbonic acid, in combination with lime, and they exhibit various forms. Crystals of phosphate of lime occur usually in the form of acicular crystals, varying from $\frac{1}{40}$ to $\frac{1}{1000}$ of

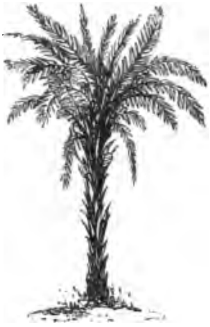

Fig. 82.

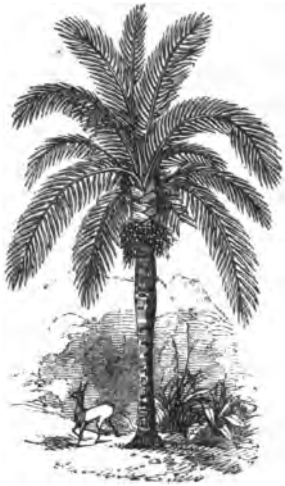

Fig. 83.

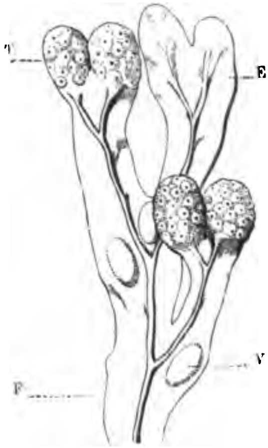

Fig. 84.

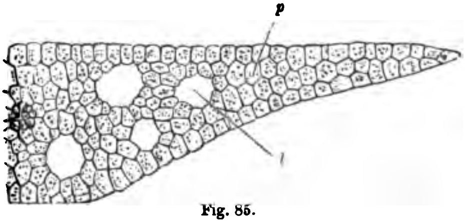

Fig. 85.

Fig. 82. Elais Guineensis, a palm growing in Guinea, the fruit of which yields the solid oil called Palm Oil.

Fig. 83. Ceroxylon Andicola, the Wax Palm of South America. It supplies wax. Its stem is called a caudex.

Fig. 84. Fucus vesiculosus, a common sea-weed, showing vesicles or bladder V, full of air. F, E, the cellular frond; T, the fructification.

Fig. 85. Vertical section of the leaf of Potamogeton or Pondweed, showing air cavities or lacunæ, *l*, and parenchymatous cells, *p*, with granules.

an inch in length (Fig. 86, R); to these the name of needles or raphides was originally given. Cells with clusters of raphides may be seen attached to the divisions between the cells in the Banana. Crystals of oxalate of lime assume an octohedral form, and vary from $\frac{1}{50}$ to $\frac{1}{250}$ of an inch in length (Fig. 87). They are abundant in the root of Turkey Rhubarb, to which they impart grittiness, and in the Old-Man-Cactus they constitute 60-80 per cent. of the dried tissue. In other species of Cactus (Fig. 88) they frequently occur. Professor Bailey states, that in a square inch of Locust-bark, about the thickness of writing-paper, more than a million and a half of these crystals are found. A good way of shewing the crystals is to boil in water a piece of Rhubarb root, or a part of the frond of Encephalartos pungens (Fig. 89), till the cohesion of the tissue is destroyed, and then the separated cells will be seen, usually containing each a cluster of raphides, as in Figure 87. The squill bulb (Fig. 90), and the bulb of the onion, exhibit raphidian cells, which are easily separated during the decay of the plants. In a single cell of the Poke (Phytolacca decandra), twenty to

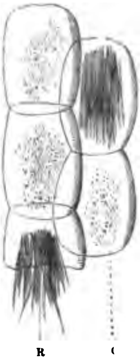

Fig. 86.

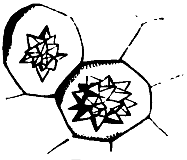

Fig. 87.

Fig. 88.

Fig. 89.

Fig. 90.

Fig. 86. Cells of Rumex, C, containing raphides, R. The cells are called Raphidian. The raphides consist of acicular or needle-like crystals united together.

Fig. 87. Cells of Beet-root, containing conglomerate crystals.

Fig. 88. Melon Cactus, a succulent plant, the cells of which contain numerous crystals or raphides.

Fig. 89. Encephalartos pungens, a Cycadaceous plant, containing starch and raphidian cells.

Fig. 90. Squilla maritima, the Squill plant, the bulb of which exhibits cells containing large crystals.

thirty crystals may be seen. Clustered crystals are also visible in the cells under the epidermis of the Marvel of Peru. Sulphate of lime occurs occasionally in the form of a single or double octohedron, or in a tabular shape. Carbonate of lime crystals, in the form of rhombohedrons, occur in species of Cycas (Fig. 37, p. 21) and Cactus. Some raphidian cells are called biforines by Morren, because, when moistened, they discharge the crystals through openings at each end. It is said that raphides may be produced artificially in the cells of rice-paper by introducing lime into them in solution under the air-pump, and afterwards putting them in a weak solution of oxalic or phosphoric acid.

64. *Siliceous matter* occurs in the walls of cells, and enters into their composition. This is the case with grasses and horsetails (Fig. 34, p. 20), and, in a remarkable degree, with those peculiar organisms supposed by Ehrenberg to be infusoria, but now referred to the vegetable kingdom under the name of Diatomaceæ.

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65. Recapitulation of the Elementary Tissues of Plants:—

1. Cells, Vesicles, or Utricles, consist of minute sacs or bladders of various forms and sizes, having their walls composed of cellulose.
2. Membranous Cells have thin walls, and contain a formative protoplasm in their interior, with nuclei and nucleoli.
3. Thickened Cells, have their walls composed of several uniform layers of ligneous matter, which is often very hard, and fills up their cavities.
4. Dotted or Pitted Cells, have their walls irregularly thickened so as to leave numerous rounded thin portions.
5. Spiral Cells, have a spiral fibre coiled up in the inside of their walls.
6. Cells contain starch, gum, sugar, lignin, oils and resins, nuclei, chlorophyll and other colouring matters, air, raphides or crystals, and nitrogenous substances.
7. Cellular Tissue, composed of various cells united.
    - *a.* Parenchyma, made up of membranous or thickened cells.
    - *b.* Inenchyma, or Fibro-cellular Tissue, made up of spiral cells.
8. Intercellular Spaces and Canals, are cavities between the cells of cellular tissue. They contain fluids and air.
9. Vessels are closed tubes of different lengths, often tapering to each end, and overlying each other, having their walls composed either of membrane alone or of membrane and fibre.
10. Membranous Vessels are thin-walled tubes, having their walls composed of membrane only, as laticiferous vessels.
11. Thickened Vessels are tubes, the walls of which are composed of several layers of ligneous matter, as woody vessels.
12. Dotted or Pitted Vessels, are tubes having their walls unequally thickened, so as to have numerous round thin portions.
13. Fibrous Vessels are tubes having a spiral fibre more less complete coiled up in their interior.
    - *a.* Spiral Vessels, with a complete spiral fibre, usually unrollable.
    - *b.* Annular Vessels, with rings of fibre.
    - *c.* Scalariform Vessels, with bars of fibre.
    - *d.* Reticulated Vessels, with irregular netted fibres.

14. Vascular Tissue, Angienchyma, is composed of various kinds of vessels combined.
    - *a.* Pleurenchyma, woody vascular tissue, either membranous, thickened, or disc-bearing.
    - *b.* Bothrenchyma or Taphrenchyma, tissue composed of dotted or pitted vessels.
    - *c.* Trachenchyma, tissue composed of spiral or annular vessels.
    - *d.* Cinenchyma, tissue composed of anastomosing laticiferous vessels.

66. List of a few of the plants which may be used by the student in his examination of microscopic vegetable tissues. Preparations of most of these are preserved in the Museum of the Edinburgh Botanic Garden :—

1. *Cells and Cellular Tissue.*—Sea-weeds; Rice-paper; independent cells, with nuclei in yeast plant (Torula Cerevisiæ); cells with nuclei and nucleoli in ripe fruit of strawberry, in the onion bulb, and in ovules or very young seeds; cells united in a linear series in common mould, confervæ, and many hairs; branching cells in many hairs, and in some moulds, as Botrytis; cells united in fours in pollen of Acacia, and in some spores of sea-weeds; cells thickened by deposit of lignin in the shell of the Coco nut, and Attalea funifera or Piaçaba palm, in the stone of the peach, cherry, and nut, in the seed of the Ivory Palm and Date, in the gritty matter of the Pear; cells with siliceous covering in Diatomaceæ. Porous cells in Elder pith, in stem of common garden Balsam (Balsamina hortensis), in the outer covering of the seeds of Gourd and Almond, in the wing of the seed of Lophospermum erubescens and Calempelis scaber. Spiral cells in leaves and stems of many orchids, as Oncidium and Pleurothallis ruscifolia, in garden Balsam, in the leaf of Sphagnum, the fructification of Liverworts, the winged seed of Sphenogyne speciosa. Annular cells in Opuntia. Filamentous cells in Mushrooms and Agarics. Hexagonal cells in pith of Elder. Stellate cells in Rush. Ciliated moving cells in Vaucheria, Fuci, and Chara. Professor F. Schulze of Rostock, states, that by means of nitric acid and phosphate of potash, the cells of plants, young or old, hard or soft, may be perfectly isolated from one another, so as to give single cells free and distinct for microscopic examination.
2. *Vessels and Vascular Tissue.*—Woody tissue in the stem of ordinary trees; the fibres may be separated by maceration from the inner bark of the Hemp-plant, Flax-plant, Elder, New Zealand Flax, Mallows, &c. Disc-bearing woody tissue in Scotch Fir, Weymouth Pine, Araucaria, Altingia excelsa, Cycas, Winter's bark tree, Illicium. Dotted Vessels in Stem of Willow, Sugar-cane, Pitcher plant. Spiral Vessels in Oncidium bicolor, Banana and Plantain, most liliaceous plants, (as Hyacinth, Lily, and Crinum) leaf of Geranium and Strawberry, Cabbage, Lettuce, Asparagus shoot; branched spirals in Long-leek and Anagallis. Annular vessels in Opuntia vulgaris, Leek, Equisetum Telmateia. Reticulated vessels in garden Balsam. Scalariform vessels in Tree Ferns, Diplazium seramporense, Asplenium pubescens, Osmunda. Laticiferous vessels in various species of Ficus, as the India-rubber fig (Ficus elastica), Gutta Percha plant (Isonandra Gutta), Euphorbias, Lettuce, Dandelion, Celandine, Goatsbeard.
3. *Contents of Cells.* — Starch-cells in Potato, angular starch granules in Rice, compound starch granules in Arrow-root, peculiar starch grains in the milky juice of Euphorbia. Air cells and lacunæ in the Rush, Sparganium ramosum, Limnocharis Plumieri, and other aquatic plants. Cells with raphides of oxalate of lime in Rhubarb root, cells with acicular crystals in Hyacinth, cells with octohèdral and prismatic crystals in Onion and Squill. Oil cells in rind of Orange and Lemon, in leaves of Hypericum, and of the Myrtle order. Chlorophyll cells in Mosses, Vallisneria, Chara; cells with colouring matter in leaf of Rottlera tinctoria, and in petals.

V. INTEGUMENTARY SYSTEM.

67. The general Integumentary covering of plants consists of cells, various, aggregated, and may be considered in connection with the elementary tissues. It has been divided into two parts—the *Proper Epidermis*, and the *Outer Pellicle* or *Cuticle*. The epidermis is formed of one or more layers of colourless thick-walled cells cohering together, so as to constitute a firm membrane, which can be pulled off from the subjacent tissue.* The colour of the epidermis in general depends on that of the parenchymatous cells below, from which it can be separated as a colourless layer. Occasionally, however, the epidermal cells contain colouring matter, as well as waxy, siliceous, and calcareous substances. In the case of Orchids (Fig. 38, p. 21), it is not uncommon to find spiral cells in the epidermis covering their aerial roots. The epidermis covers all parts of plants exposed directly to the air except the stigma, which is formed of loose cells at the upper part of the pistil or central organ of the flower. The epidermis is sometimes much thickened, as in the Oleander and American Aloe, by being composed of numerous layers of cells, while, at other times, it is very thin. A delicate epidermis, called *Epithelium*, lines the internal cavities of certain organs, such as the ovary, containing the young seeds. The boundaries of the epidermal cells frequently assume a waved or sinuous aspect (Fig. 93). The outer cuticle is a thin layer covering the true epidermis, and apparently formed from the cells of the latter. It may be merely a changed condition of the walls of these cells, or a modification of the intercellular substance (¶ 40 and 52) which surrounds the cells. It forms the covering of hairs, as seen in Figure 91, which represents the cuticle of the cabbage with hairs, *h*, and it extends into certain openings in leaves called stomata (Fig. 91, *s*). In plants constantly under water, and in certain of the lower tribes, the cuticle is the only integumentary covering. The outer cuticle is considered by Mitscherlich as a corky substance, which prevents the penetration of moisture. The same substance is considered by him as cementing the cell-walls

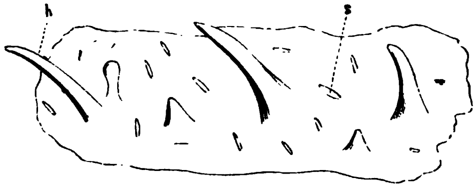

Fig. 91.

Fig. 91. Cuticle, or outer integument of the Cabbage (*Brassica oleracea*), showing the covering of the hairs, *h*, and the openings called stomata, *s*.

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* For a fuller notice of the Epidermis, see subsequent remarks on the structure of leaves. See also Mohl, Recherches sur la Cuticule des plantes. Ann. des Sc. Nat. 2d Ser. Bot. t. xix. p. 201, and Linnæa for 1842. Carpenter thinks that the term Epidermis as regards plants should be dropped as being inappropriate. He adopts the term Cuticle for the general integument. Physiology, 3d Edit., p. 767.

(¶ 52). Hairs having this corky covering do not absorb fluids easily. Hence the reason why fresh cotton-wool imbibes water with difficulty. If the corky layer be removed by chlorine, or some other oxidizing agents, the wool may be moistened as readily with water as any other substance which consists only of cellulose. Before treatment with chlorine, cotton-wool can hardly be impregnated with mordants; while, after bleaching, the colours are easily imparted.

68. *Epidermal Appendages.*—These consist of openings, to which the name of stomates is given, as well as of hairs, glands, and scales. They are not invariably present in the epidermis of all plants, and some of them, after having been developed, disappear in the progress of plant growth. Their presence and absence, as well as their form and structure, give rise to important botanical characters. The botanical terms used to indicate the nature of the hairs covering plants will be given in the Glossary at the end of the volume.

69. *Stomata* or *Stomates*, called also breathing pores, are orifices between the epidermal cells situated on the leaves and other green parts of plants exposed to the air, and communicating with intercellular spaces. These openings are bounded by two (sometimes three or four) cells (Figs. 92, 93), of a delicate nature, which have the power of opening or closing the orifice. When moist, these cells become swollen, and, while they lengthen, curve outwardly in the middle, so as to leave a free opening; when dry, they are shortened and straightened, and thus their sides are applied to each other, so as to close the orifice. They are not found in underground roots, nor in plants which have grown excluded from light; and they are rarely seen in those which are constantly under water. They are best seen on the under

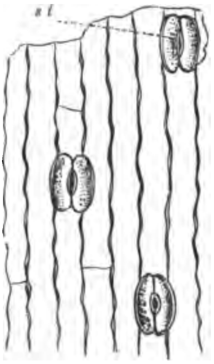

Fig. 92.

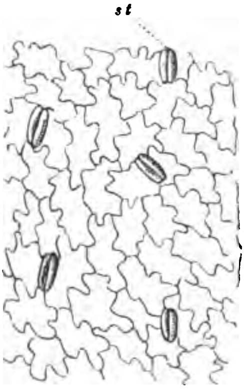

Fig. 93.

Fig. 92. Epidermis of Lily, showing the lines bounding the compressed and elongated cells, and stomata, *s t*, composed of two cells, with an opening or slit between them. Some granular matter is seen in the stomatic cells.

Fig. 93. Epidermis of the garden Balsam, Balsamina hortensis, showing wavy lines bounding the flattened cells, and stomata, *s t*, of an elliptical form.

surface of leaves, and will be again noticed when treating of these organs. When the epidermis becomes hard and glazed, stomata sometimes disappear, and are altered in their appearance. Their form is usually oval or elliptical (Figs. 91, *s*, 92, 93, *st*), but in some instances they are spherical or quadrangular. They are either scattered singly at regular or irregular intervals over the epidermis, or they are arranged in clusters. Their number varies from 200 to 160,000 or more in a square inch of surface. In the leaves of the white lily there are 60,000 in a square inch on the under surface, and about 3000 on the upper; on the leaves of the cherry laurel there are 90,000 on the lower surface, and none on the upper.

70. *Hairs* are prolongations of the epidermal cells. They consist either of single cells, more or less elongated, (Fig. 91, p. 40, and Fig. 94), or of several cells placed in a linear series, like beads, as in Figures 95, 96, or united both longitudinally and laterally, as in Figure 97, where the lower part of the hair consists of numerous cells. In Figure 98, the hair divides at the apex into two, in a forked manner. In Figure 99, *a*, it splits into several cellular projections, which, in the lower figure, *b*, are represented spreading out in a star-like or stellate manner. A forked hair (Fig. 98) sometimes has the divisions hooked (uncinate), or presenting a barbed (glochidiate) appearance. In Figure

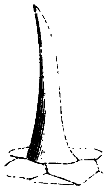
Fig. 94.

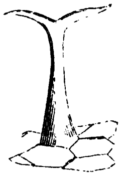
Fig. 98.

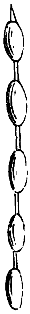
Fig. 96.

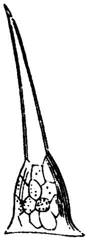
Fig. 97.

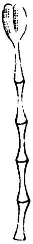
Fig. 100.

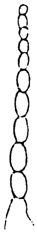
Fig. 95.

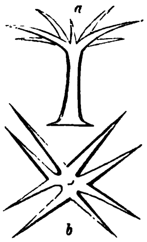

Fig. 99.

Fig. 94. Hair of common Cabbage; it is composed of a single elongated conical cell. Such a hair is called simple and unicellular.

Fig. 95. Hair of Virginian spiderwort (*Tradescantia virginica*), composed of numerous cells united in a linear series. It is called a partitioned hair.

Fig. 96. Hair of Marvel of Peru (*Mirabilis Jalapa*). It is moniliform or necklace-like, being composed of separate cells with contractions.

Fig. 97. Sting (stimulus) of Nettle (*Urtica dioica*); its base is formed by numerous cells containing irritating fluid; from these arise a simple unicellular conical hair, which serves as a duct for conveying the fluid.

Fig. 98. Forked or bifurcated unicellular hair of Draba or Whitlow-grass, one of the cruciferous plants.

Fig. 99. Unicellular hair *a*, of Alyssum, dividing into rays at the apex. The stellate or starlike arrangement is represented in the lower figure *b*.

Fig. 100. Glandular multicellular, or many-celled hair of Frogsmouth (*Antirrhinum majus*). It is a partitioned capitate hair. The glands in Fig. 100 and 103, are at the apex of the hair, while in Fig. 97 they are at the base.

100 is seen a capitate hair having a rounded top. Hairs are sometimes attached to seeds, as in the Cotton plant (Fig. 101), for the purpose of scattering them. The cotton hairs consist of elongated cells, the walls of which in drying collapse in the centre, so as to present a twisted appearance. Various parts of plants are transformed into hairs. Thus, in Rhus Cotinus or the Wig-tree (Fig. 102), the flower-stalks are changed into hairs, and in the common Dandelion and other composite plants, (Fig. 105), the outer covering of the flower, called the calyx, assumes a hairy or pappose aspect. Hairs which have secreting cells at their apex, as in the Chinese Primrose, and in Sage (Fig. 103), and in Frogsmouth (Figs. 100 and 104), are called glandular. The cells of the hairs occasionally secrete colouring matter, more especially when they arise from parts of the flower, as in the Iris and Virginian Spiderwort. When the cells of hairs are hardened by deposits, as in the Rose (Fig. 106) and Bramble, they are called Prickles (aculei). Bristles (setæ) are rigid hairs usually formed of a single cell; while stings (stimuli), as in the common Nettle (Figs. 97 and 107) and Chili Nettle, are stiff hairs arising from a series of cells which secrete an irritating fluid. The scales produced on the

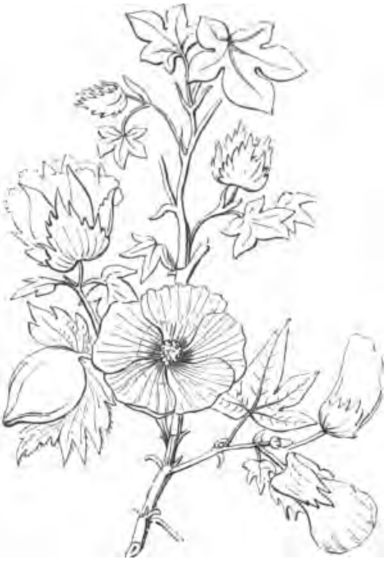

Fig. 101.

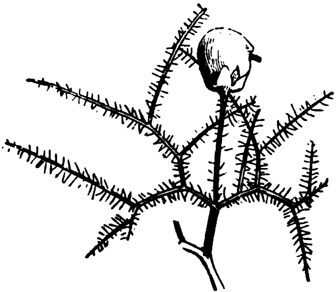

Fig. 102.

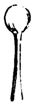

Fig. 103.

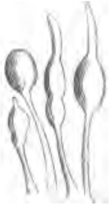

Fig. 104.

Fig. 101. Gossypium herbaceum, the Cotton plant. The hairs surrounding the seeds constitute cotton. The hairs, when the seed is ripe, exhibit a peculiar twisted appearance under the microscope. The Cotton plant is said to be indicated by the word Karpas, translated in Esther i. 6, green.

Fig. 102. Flowering branch of Rhus Cotinus, a kind of Sumach. One of the branches is seen bearing the fruit. The others produce hairs, and are sterile. The tree is called arbre à perruque, or the Wig-tree, on this account.

Fig. 103. Glandular unicellular hair of Salvia. The hair is called capitate, from its rounded head.

Fig. 104. Glandular unicellular hairs of Frogsmouth (*Antirrhinum majus*).

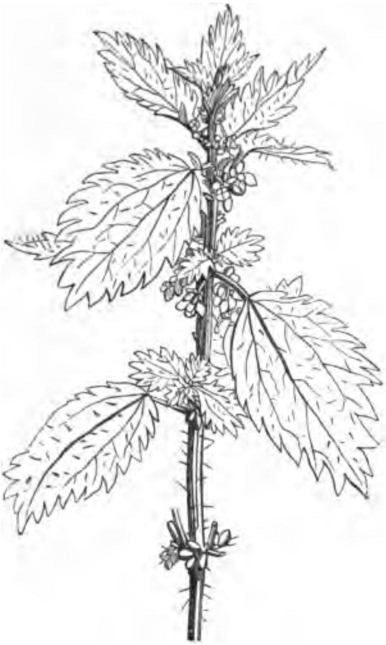

Fig. 107.

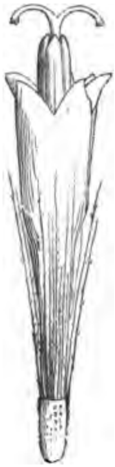

Fig. 105.

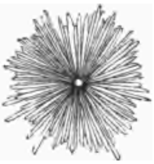

Fig. 108.

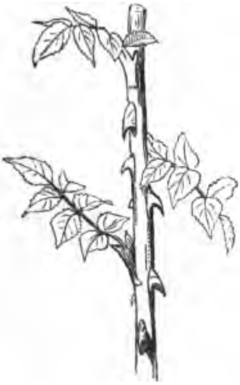

Fig. 106.

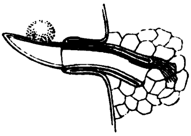

Fig. 109.

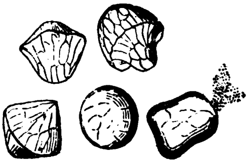

Fig. 110.

Fig. 105. Flower of Senecio, one of the composite plants, shewing the Calyx in the form of hairs or pappus.

Fig. 106. Rose branch, shewing aculei or prickles, which are hardened hairs.

Fig. 107. Urtica urens, a species of nettle, with its leaves covered with stinging hairs like those represented in Figure 97.

Fig. 108. Radiating hair or scale in Elæagnus, the Oleaster. Such scaly hairs frequently give out waxy and other secretions.

Fig. 109. Collecting hair on the pistil or central organ of the flower of Campanula or Harebell. The upper part of the hair which bears a pollen-grain, is partially drawn within the lower portion.

Fig. 110. Superficial glands of the Hop, containing a resinous secretion, called Lupulin.

leaves of Oleaster (Fig. 108), and of some Begonias, the scurf on those of Bromelias, the chaff (ramentum) covering the fronds of Ferns, are all modifications of epidermal cellular tissue. On the central part of the flower of the hare-bells peculiar hairs are seen, the upper part of which is retracted within the lower (Fig. 109) at a certain period of growth. These hairs are called collecting hairs, inasmuch as they collect the powder which falls from the stamens. In the germs of some sea-weeds vibratile hairs called cilia (Fig. 1, p. 2, and Figs. 31, 32, and 33, p. 20) are seen.

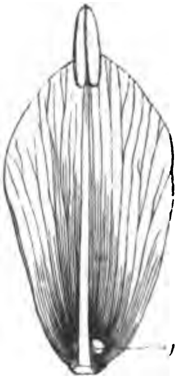
Fig. 111.

71. *Glands* are epidermal cells containing various fluid and solid secretions. They are either applied closely to the surface (sessile), as in the Ice-plant, where they appear as elevations of the epidermis, containing a transparent fluid like ice, or in the Hop (Fig. 110), where they appear as resinous scales of different shapes; or they are raised on stalks (stipitate) of different lengths, and then may be called glandular hairs, as in the Sundew. The bases of undeveloped hairs sometimes assume the appearance of glands. The secretions of glands are of an oily, waxy, resinous, gummy, saccharine, saline, acid, or irritant nature. The honey-like matter of the flower is secreted by glands. In Figure 111 is represented one of the leaves of the flower of the Crown-imperial, showing the depression, *g*, at its base, in which the honey is secreted; a similar pit is seen in the common Buttercup. The cells at the base of the Nettle hair (Fig. 97) contain an irritant secretion, those at the apex of the Sundew hairs contain viscid matter. The glands on the flower-stalk of Dittany and Rose secrete oil, while those of the Chick-pea have an acid fluid in their interior. Mr. Weddell states that on the inner surface of the base of the stipules of Cinchona and allied genera, there are numerous small sessile glands which secrete a gummy fluid. In Cinchonas the secretion is transparent and fluid, while in several other genera it is solid and opaque, and seems to glue the stipules to the bud which they embrace; this is particularly the case in Pimentelia glomerata. In Rondeletia the secretion is soft, like wax, and of a beautiful green colour. The inhabitants of Peru give it the name of Aceite-Maria; they collect it carefully, and use it as an external application in various diseases. The stipular glands have an oval or lanceolate form, and are somewhat pointed. These glands can be detected in fresh specimens of Cinchona Calisaya, Burchellia capensis, Cephaelis Ipecacuanha, Coffea arabica, Ixora javanica, Mussænda frondosa, Rondeletia speciosa, Pavetta indica, Luculia gratissima and Pinceana, Pentas carnea, Gardenia Stanleyana, and other species.

Fig. 111. One of the petals or leaves of the flower of Fritillaria imperialis, Crown Imperial, shewing a pit or depression *g* at the base containing a honey-like secretion. This gland is sometimes called a nectary. A stamen is attached to the petal.

72. List of a few plants which may be employed in examining the Integumentary System :—

Epidermis of leaves, as Hyacinth; epidermal cells of the flowers of Pelargonium, of the Apple, and Foxglove; siliceous cuticle of Equisetum, Bamboo, stalks of Wheat, and other grasses; hairs of Cotton; articulated hairs on leaves of Goldfussia and Alstroemeria ovata; moniliform hairs in flowers of Virginian Spiderwort; stellate hairs on leaves of Deutzia scabra, Rottlera tinctoria, and in air cavities of Nuphar lutea, or yellow Water lily; peltate hairs on leaves of Malpighia urens; forked hairs on leaves of Alyssum; glandular hairs on the leaves of the Nettle, Chinese primrose, and Drosera or Sun-dew; spiral hairs, or, in other words, spiral cells, on the outer covering of the seeds of Collomia, Cobæa, and many Polemoniaceous plants, also of Acanthodium spicatum, and on the fruit of Salvia; glands, with oil, in Sweet-briar; scaly glands, which may be called a modification of hairs, on the leaves of Elæagnus and some Begonias; elliptical stomata on the leaves of liliaceous plants, as the Hyacinth and Lily; square stomata on Agave leaf; hair-like stomata on leaf of Oleander; clustered stomata in some Begonias; and siliceous pectinate stomata in Equisetum. For a full account of the Chemico-Histological constitution of the Cuticle, of the Epidermis, and of the various appendages of the Integumentary System, see Mulder's Chemistry of Organic Bodies, translated by Fromberg. For Epidermal Structure, see Brongniart, sur la Structure de l'Epiderme des Vegetaux. Ann. des Sciences Nat. 2d Ser. part. Botan. tom. i. p. 65.

CHAPTER II.

NUTRITIVE ORGANS OF PLANTS.

73. Having now considered the elementary tissues of plants, their composition, and contents, we proceed to view them in combination, as forming various compound organs. These are naturally divided into the organs destined for the nourishment or nutrition of the plant, and those concerned in reproduction, or in the formation of the new plant. Viewed as individual beings, plants present various aspects. Some, like the red-snow plant (Protococcus nivalis) and Oscillatoria, are composed of single isolated cells, which are capable of performing the functions both of nutrition and reproduction. Others, as Fungi (Fig. 11, p. 11) and sea-weeds (Fig. 30, p. 20, and Fig. 84, p. 37), are composed of numerous cells, united either in a linear series or as a flattened expansion, some of which are appropriated to the nutritive, and others to the reproductive functions. These plants are denominated *Cellular*. The higher classes of plants have cells and vessels combined, presenting more complicated organs of nutrition and reproduction, and they are denominated *Vascular*.

74. In the lower classes of plants there are no evident flowers—their organs of reproduction are obscure, and hence they are called *Flowerless* and *Cryptogamic*, while the higher classes have conspicuous flowers, and evident organs of reproduction, and hence are called *Flowering* and *Phanerogamous* or *Phœnogamous*. In both classes the young plant, or embryo, in its earliest state, is cellular. This state is retained by the embryo or spore (Fig. 1, p. 2) of the former; while in the latter it assumes a high degree of development in the seed, and at maturity exhibits the parts which are to form the root, stem, and leaves, associated with certain temporary leafy appendages, or lobes, called cotyledons (Fig. 112).

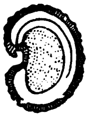
Fig. 112.

75. When the spore of Cryptogamic plants is sown in the soil, it gives off root-like processes, and either sends upwards a conspicuous stem with leaves, or produces a peculiar flattened expansion, called a *frond* or *thallus* (Figs. 14, 15, p. 12), bearing organs destined for forming spores. In Phanerogamous plants, on the other hand, when the seed

Fig. 112. Seed of Lychnis or Campion cut vertically, shewing the embryo plant coiled up in the interior. The narrow line, at the upper extremity of the embryo, points out the division of the two cotyledons. The other extremity is the radicular portion of the axis whence the root arises.

is planted, the young root of the embryo, proceeding from one end of the primary axis, descends, while the stem ascends, bearing leaves and conspicuous flowers. This process is represented in Figure 113,

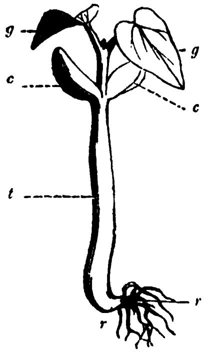

Fig. 113.

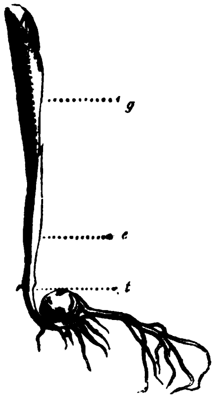

Fig. 114.

where *r* is the young root coming off from the radicular end of the axis; *t* is the stalk supporting the cotyledons *c c;* and *g g* are the first leaves of the plant. The same process is seen in Figure 114, where the roots are seen proceeding from the lower part of the axis *t;* a single cotyledon is seen at *c;* and the young stem is marked *g*.

76. When we take a comprehensive view of the Vegetable Kingdom, we find that all the organs of plants are formed upon one harmonious plan. All are produced from cells, which are modified and aggregated in various ways, and are fitted for the special functions performed by the different parts of plants. The organs called Root, Stem, and Leaves, with their modifications, are those destined for nutrition or vegetation; while certain cellular bodies in Cryptogamic plants, and the Flowers in Phanerogamous plants, are the organs of reproduction.

I. THE ROOT OR THE DESCENDING PORTION OF THE AXIS.

77. The root (Fig. 113, *r*), generally speaking, is that part of the plant which descends into the soil, avoiding the light. It is the first organ developed from the axis of the embryo. The por-

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Fig. 113. Haricot or French bean, a Dicotyledonous plant, germinating. *r*, the roots coming off from the radicular end of the axis; *t*, the stalk bearing the cotyledons *c c*; the young stem and leaves *g g*.

Fig. 114. Grain of Maize or Indian Corn, a Monocotyledonous plant, germinating. Roots come off from lower end of *t*, the axis; *c*, the single cotyledon; *g*, the young stalk and leaves.

tion of the axis from which it arises is called radicular. In Figure 115, the embryo of a pea exhibits, at *r*, the portion of the axis from which the young root proceeds. This portion is called the *Radicle;* while the part, *t*, is connected with the ascending axis bearing the cotyledons, *c c*, and the young stalk, *g*, which lies in a depression, *f*, of the cotyledons. The root consists at first entirely of cellular tissue; and, in cellular plants, this continues to be the case throughout life. In vascular plants it is strengthened by the addition of woody fibres and vessels, and presents the same internal structure as is seen in the stem. It may be considered a downward prolongation of the stem.

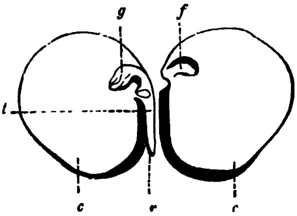

Fig. 115.

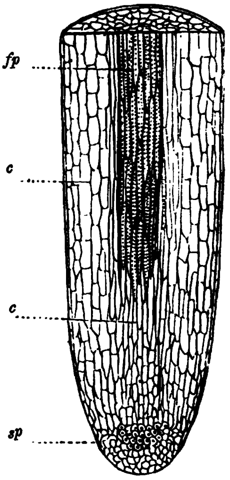

Fig. 116.

78. The extremities of the roots are composed of loose cells, which appear to be the terminal tissue of the radicle, carried forward by the elongating root. These cells have been called *spongioles*, or *spongelets*, but they ought not to be reckoned special organs. They do not consist of the newly-formed tissues, but they are in reality an annual mass of older cells, pushed forward by the root as it is developed, and when they decay, they are replaced by the layer beneath. Thus, according to Schleiden, the point of the root consists of older and denser tissue than that immediately behind it. In the structure of the root we do not meet with true spirals. The epidermal covering does not present stomata; but hairs, usually formed of a single elongated cell, are produced, often in great abundance, which appear to serve the purpose of absorption. Figure 116 represents the magnified extremity of a young root of Orchis; *c c* being the cellular tissue, passing into fusiform dotted cells and vessels, *f p;* the cellular extremity of the root, called the spongiole, being marked *s p*. The extremities of some roots, as those of Duckweed and Pistia, are covered by a little cap-like process, or calyptra, which consists of a cellular layer, separating from the external parenchyma, but still retaining its connection with the point of the root, which perishes if the covering is removed. In Figure 117, there are seen two plants of Lemna minor, or lesser Duckweed, with their roots enclosed in a cellular sheath,

Fig. 115. The Dicotyledonous embryo of the pea laid open, magnified. *c c*, the two fleshy cotyledons, or seed-lobes, which remain under ground when the plant sprouts; *r*, the radicular extremity of the axis whence the root arises; *t*, the axis bearing the young stalk and leaves, *g*, which lie in a depression of the cotyledons, *f*.

Fig. 116. Vertical section of an Orchis root, highly magnified. The cells, *c c*, gradually pass into dotted cells and vessels, *f p;* the extremity of the root, called a spongiole, *s p*.

or pileorhiza.* Hairs are found on the roots of many plants, as on the roots of Orchids, on the aerial roots of Ivy, on grasses, as Piptatherum multiflorum and common maize, on the British species of Drosera, where the simple roots, which contain abundant starch granules, and perform the office of the thickened roots of some Orchids, are constantly submerged, and are coated with cellular filamentous processes. It is probable, Berkeley says, that the presence of hairs on roots is a very frequent phenomenon, though only recently observed. The hairs on roots seem to be without partitions. Some have a simple internal cell-wall, others have a spiral structure developed either through the whole or a portion of the thread.

79. The young roots of Cryptogamic plants, which have no cotyledons, or seed-lobes, arise from every part of the surface of the cellular axis or spore (Fig. 1, p. 2), and they are called by Richard *Heterorhizal.* In Phanerogamous plants, having one seed-lobe, or cotyledon, and hence called Monocotyledonous (Fig. 118, *c*), the young roots arising from the radicular portion of the axis separate into numerous fibres (Fig. 118, *r*), which, in piercing the axis, are covered with a

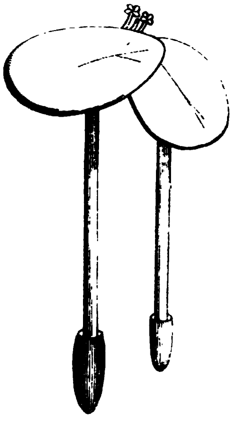

Fig. 117.

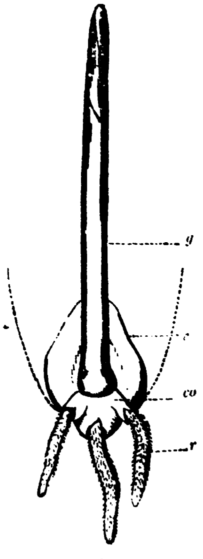

Fig. 118.

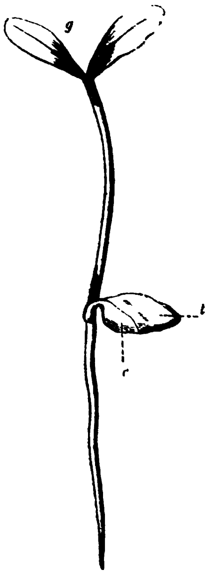

Fig. 119.

Fig. 117. Magnified representation of two plants of Lemna minor, or Lesser Duckweed—the green mantle of the pools—shewing the extremities of the roots covered by a cellular sheath.

Fig. 118. Grain of Oats sprouting. The roots, *r*, passing through sheaths, *co*, the single cotyledon, *c*, and the young stalk and leaves, *g*. Richard calls it Endorhizal.

Fig. 119. Seed of Orange, a Dicotyledon, sprouting, shewing the root descending aud tapering. *c*, the cotyledons in the seed, *t*; the young leaves, *g*. The plant is called Exorhizal by Richard.

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* See Trecul on Roots, in Annales des Sciences Nat., 3d ser. tom. v. p. 340.

sheath, called a coleorhiza (Fig. 118, *co*). These roots have been called *Endorhizal.* Schleiden considers them as being adventitious. In Phanerogamous plants, having two seed-lobes, or cotyledons, and hence called Dicotyledonous, the young root elongates directly from the extremity of the radicle (Fig. 119), and afterwards divides. It is called *Exorhizal.* These divisions of Richard are not adopted by Schleiden.

80. Roots have no proper leaf-buds; but in certain circumstances they are capable of producing them. Roots occasionally arise from different parts of the stem. Thus, when a cutting of willow is placed in moist earth, or branches are bent so as to be inserted into the ground, roots are given off, in the form of cellular prolongations, from the surface, or from small lenticular points (Fig. 120, *l*), to which the name of lenticels has been given by some.* Such roots are *adventitious*, *secondary*, or *abnormal.* The term *Aerial*, is given to roots which arise from the stem and branches of plants, and which, during the whole or part of their growth, are suspended in the air. Remarkable instances of these aerial roots are seen in the Banyan tree (Fig. 121), and in various other species of fig; in the Screw pine (Fig. 122, and Fig. 167, p. 70), in the Mangrove (Fig. 123), and in the Tree-fern (Fig. 165, p. 70). The extremities of these roots, when in the air, are sometimes covered, as in the Screw pine, with a peculiar cap-like covering. These abnormal roots ultimately reach the soil, and become subterranean, serving to support and prop up the trees to which they are attached.

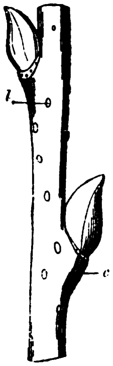

Fig. 120.

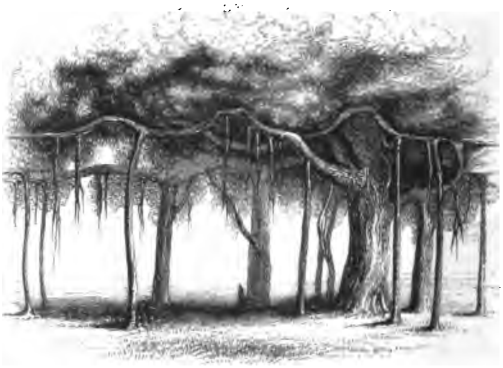

Fig. 121.

81. In Epiphytes, or plants growing in the air, attached to the

Fig. 120. Branch of Willow shewing lenticels, *l*, and buds. The scars of the old buds are marked *c*.

Fig. 121. Ficus Indica, the Banyan tree, sending out numerous adventitious roots, which reach the soil, and prop the branches. The famous Nerbuddah Banyan is said to have 300 large, and 3000 small aerial roots, and to be capable of sheltering 3000 men.

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* Mohl, sur les Lenticelles. Ann. des Sciences Nat. 2d ser. x. 33. Unger, sur les Lenticelles. Ann. des Sciences Nat. 2d ser. x. 46.

trunks of trees, such as Orchids (Fig. 38, p. 21), the aerial roots produced do not reach the soil. They continue always aerial and greenish,

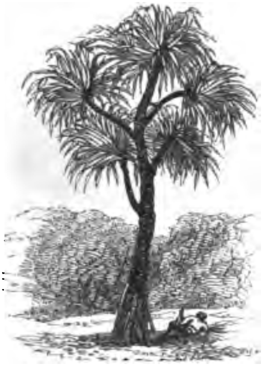


Fig. 122.

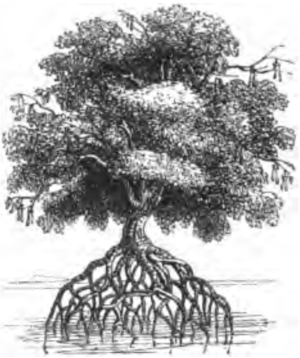


Fig. 123.

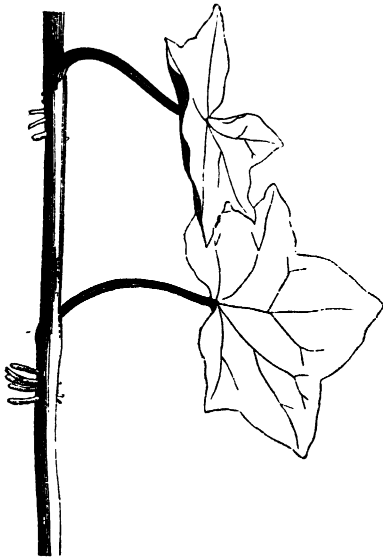


Fig. 124.

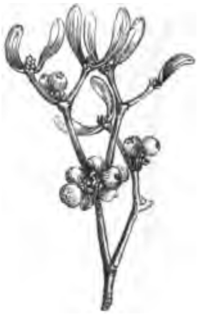


Fig. 125

Fig. 122. Pandanus odoratissimus, the Screw pine, giving off numerous aerial roots near the base of its stem.

Fig. 123. Rhizophora Mangle, the Mangrove tree, supported, as it were, upon piles by its numerous roots, which raise up the stem. The plant grows at the muddy mouths of rivers in warm climates. Mangroves are constituted by Avicennias and Rhizophoras. Avicennias have asparagus-like underground stems, which send up innumerable young shoots whenever the main stem is disturbed. Rhizophoras send out aerial roots which preserve the trees from falling after the terrestrial roots have lifted them high above the original level of the ground.

Fig. 124. Climbing branch of Hedera Helix, the Ivy, shewing the root-like processes by which it supports itself. These are not true roots. De Candolle calls them *crampons*.

Fig. 125. Viscum album, the Mistleto, a parasitic plant, deriving nourishment from the plants to which it is attached.

and they possess stomata. Delicate hairs are often seen on these Epiphytal roots, as well as a peculiar investment over their true epidermis.

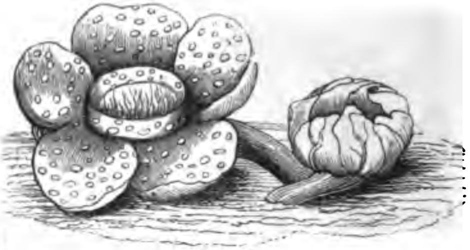
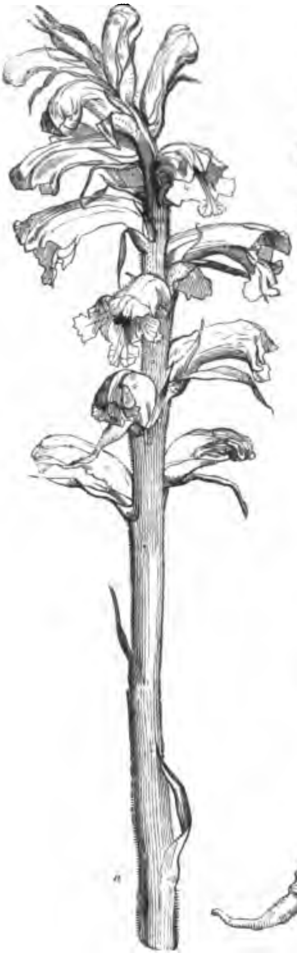


Fig. 127.



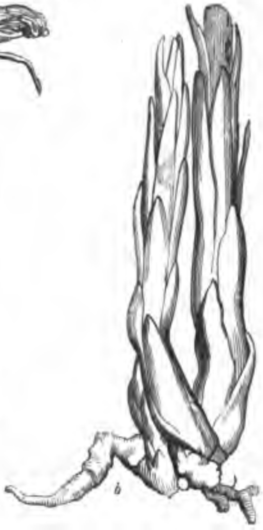


Fig. 126.

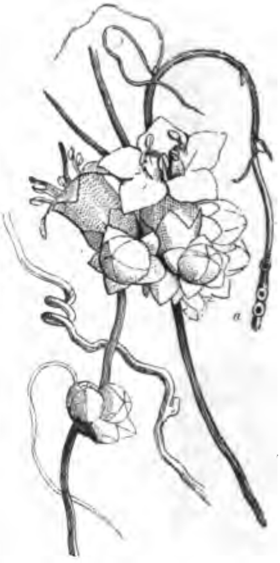


Fig. 128.

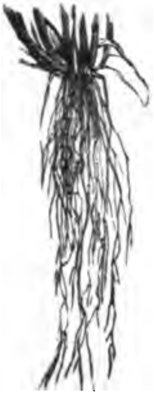
The aerial roots of the Ivy (Fig. 124), and those of Trumpet creepers, are not the proper roots of the plants, but simply processes intended for mechanical support.

Fig. 126. Orobanche Eryngii, a kind of Broom-rape, parasitic on the roots of the Eryngo. *a*, the flowering stem; *b*, the lower part of the stem, with the root, from the point of which fibrils proceed, uniting it to other plants.

Fig. 127. Rafflesia Arnoldi, a parasitic plant of Sumatra. The flower is three feet in diameter. It grows attached to the stem of a climbing Cissus.

Fig. 128. Cuscuta or Dodder, a parasite which first grows in the usual way, from seed, with its roots in the ground, but ultimately twines round other plants, and becomes attached to them by means of the rounded suckers represented on the slender branch, *a*, in the figure.

82. Parasitic plants, as the Mistleto (Fig. 125), Broom rape (Fig. 126), and Rafflesia (Fig. 127), send root-like processes into the substance of the plant whence they derive nourishment. In the Dodder (Fig. 128), the bark over the root swells into a kind of sucker (haustorium), which is applied flat upon the other plant, and ultimately becomes concave, so as to attach the plant by a vacuum. From the bottom of the sucker the root protrudes which penetrates the supporting body. In the case of parasitic Fungi, such as mould (Fig. 11, p.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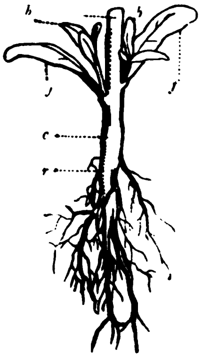


Fig. 130.

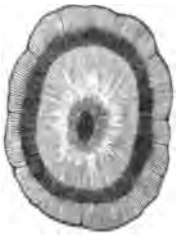
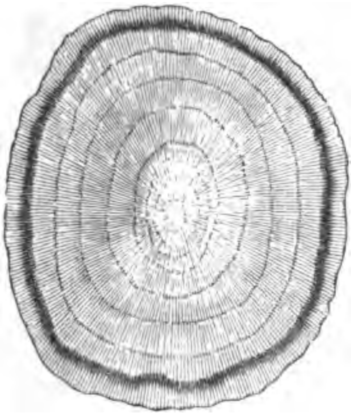


Fig. 131.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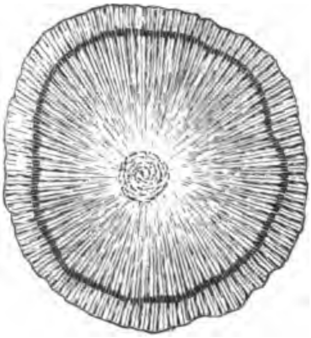
Fig. 133.

Fig. 129. Fibrous root of a grass. Numerous fibrils coming off from one point.

Fig. 130. Lower part of the stem and root of Matthiola or Stock. *r*, the tap-root, giving off slender branches; *c*, the point of union between root and stem *t*; *f f*, the leaves; *b b*, buds.

Figs. 131, 132, 133. Root of Cocculus palmatus, the Calumba, shewing concentric woody circles and rays running from the centre to the circumference.

11), there are cellular filaments which spread among the tissues of plants, and which may be looked upon as equivalent to roots and stems united. They form the spawn or mycelium of these plants, and in some cases cause rapid destruction of the tissues of plants, as in the disease called Dry-rot.

83. Roots vary in their duration. In plants which grow up, flower, and die in one year, they are annual. In such cases they are usually composed of slender fibrils, which are deciduous, like leaves. These roots, consisting of numerous fibrils, springing from one point, are called *fibrous* (Fig. 129). They are seen in many annual grasses. Plants which spring from seed one year, and flower the second season, and then die, have *biennial* roots; while those which continue to live and flower for many years, have *perennial* roots. In the last two cases the roots are often of a fleshy or woody consistence (Fig. 130).

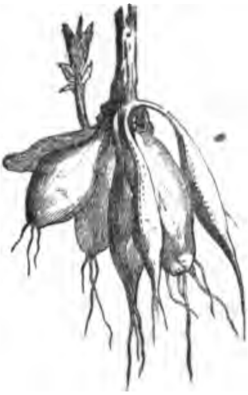
Fig. 135.

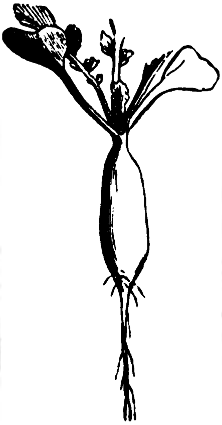
Fig. 134.

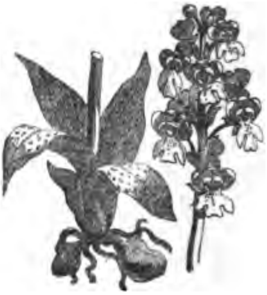
Fig. 136.

84. Perennial woody roots, when cut transversely, as in Figures 131, 132, 133, exhibit a structure similar to that seen in stems. Thus, in these figures there are observed rays going from the centre to the circumference, with a kind of bark outside, and in Figure 132 there are concentric woody circles. Fleshy roots contain much starch, sugar, and gelatinous matter in their structure. They either descend singly, in an elongated tapering form, without branching, giving rise to various forms of *tap-root*—conical in the carrot, fusiform or spindle-shaped in the radish (Fig. 134), or napiform in the turnip—or they branch off in a fibrous-like manner, giving rise to *fasciculated* roots, as in Ranunculus and Dahlia (Fig. 135), and *tuberculate* or *tuberous* roots, as

Fig. 134. Fusiform or spindle-shaped root of Raphanus sativus, the Radish.

Fig. 135. Fleshy or fasciculated roots of the Dahlia.

Fig. 136. Orchis, shewing tubercules or tuberous roots, which contain a gummy matter called Bassorin.

in Orchis (Fig. 77, p. 33, and Fig. 136). In Ipecacuan (Figs. 137, 138.) there is a peculiar *annulated* root, shewing contractions at short intervals, while in Spiræa Filipendula (Fig. 139), the root becomes *nodose*, presenting irregular swellings on its fibrils. Occasionally a tap-root is suddenly arrested in its growth, or, in place of tapering to a point, ends abruptly. This is seen in the Bitten-rooted Scabious, the root of which is called premorse. In some cultivated plants, as turnip, the central root is sometimes injured, so as to end abruptly, and it then divides into numerous branches, resembling a fasciculated root. This gives rise to the disease called Anbury or fingers and toes, which is very injurious to the crop. Its cause is now under investigation by Dr. Anderson. The mode in which the fibres of roots are produced and developed, thus gives origin to different forms of Rhizotaxis, or root-arrangement.

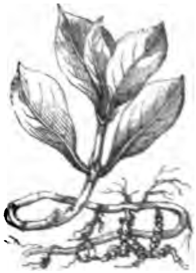

Fig. 137.

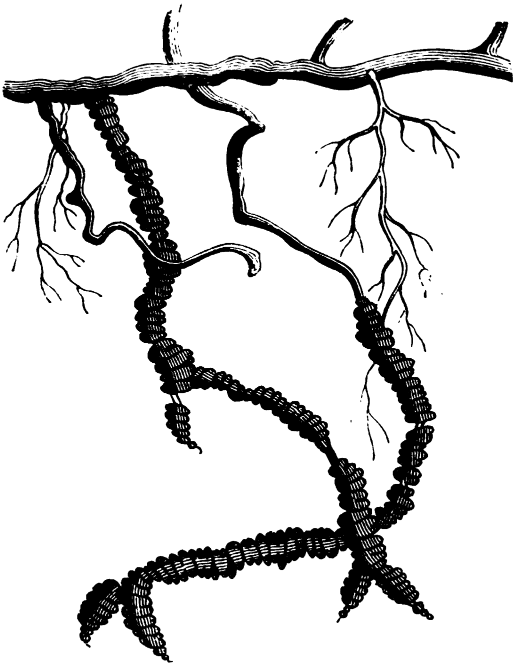

Fig. 138.

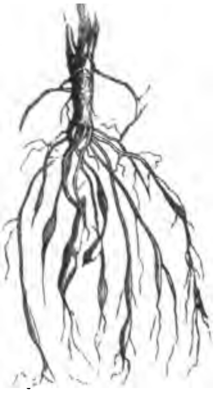

Fig. 139.

Figs. 137 and 138. Cephaelis Ipecacuanha, Ipecacuan plant, shewing moniliform or annulated roots. Fig. 139. Nodulose roots of Spiræa Filipendula.

II. THE STEM OR THE ASCENDING PORTION OF THE AXIS.

1. VARIOUS FORMS OF STEMS AND BRANCHES.

85. The stem is the ascending portion of the axis which is developed in an opposite direction from the root (Fig. 115, *g*, p. 50.) It differs from the latter in usually seeking light and air, in bearing leaf-buds, which are produced at regular intervals, and in growing throughout its whole extent. In flowering plants conspicuous stems are met with, which differ in their texture, some being *herbaceous*, and dying down annually to the ground, others being *woody* and permanent, as in trees and shrubs. When stems are weak and trail on the ground, they are called *prostrate* or *procumbent* (Fig. 140); when such stems rise towards their extremity they are *decumbent*, and when they rise obliquely from near the base they are *ascending*. Some stems are so slender that they require the aid of other plants for their support. They are either *climbing* and *scandent* plants, such as the Passion-flower, which clings to other plants by tendrils, or the Ivy (Fig. 124, p. 53), which adheres to rocks and walls by its root-like processes; or they are *twining*, when the whole stem coils round other plants in a spiral manner, the coils being either from right to left, *i. e.*, to a person supposed to be in the centre of the coil, and the stem twining across his chest from his right to his left, as in Convolvulus, Calystegia (Fig. 141), Phaseolus vulgaris, and Dodder; or from left to right, as in the Hop (Fig. 142) and Tamus; or from right to left, and left to right alternately, as in the Bryony. Dutrochet points out, that there is a revolving movement in the summit of stems, a spiral rolling of the stems round their supports, a torsion of the stems on themselves, and a spiral arrangement of leaves—all these being in each plant in the same direction. These phenomena, he says, are owing to an internal vital force, which causes a revolution round the central axis of the stem.

86. Names are given to plants according to the nature and duration of their stems. *Herbs*, or herbaceous plants, have stems which die down annually. In some of them the whole plant perishes after flowering; in others, the lower part of the stem forming the *crown of the root* remains, bearing buds, from which the stem arises next season. In what are called *biennial* herbs, the whole plant perishes after two years, while in *perennial* herbs the crown is capable of producing stems for many years, or new annual products are repeatedly added many times, if not indefinitely, to the old stems. The short permanent stem of herbaceous plants is covered partially or completely by the soil, so as to protect the buds.

87. Plants producing permanent woody stems are called *trees* and

shrubs. The latter are less than five times the height of a man, and produce branches from or near the ground; while the former have conspicuous trunks, which attain at least five times the height of a man. Shrubby plants of small stature are called under-shrubs or

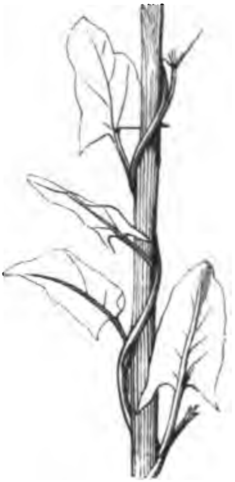

Fig. 141.

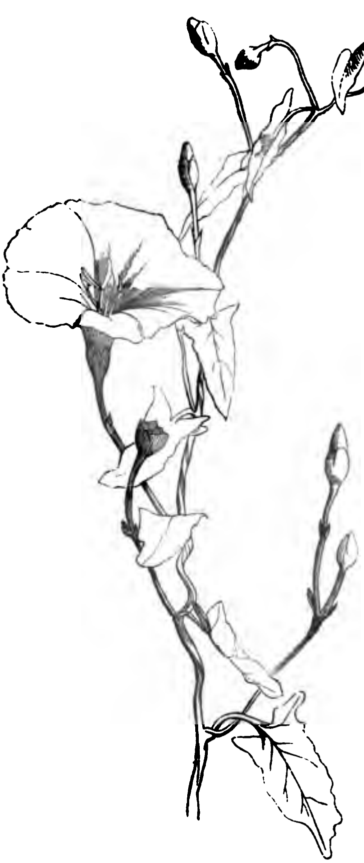

Fig. 140.

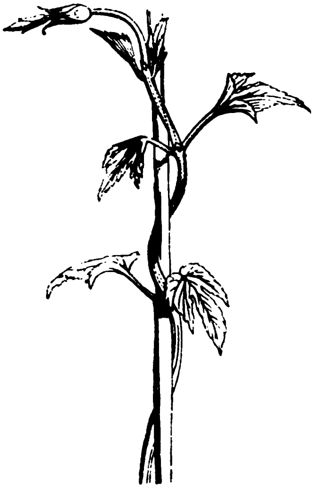

Fig. 142.

Fig. 140. Convolvulus arvensis, common bindweed, with a prostrate or procumbent stem.

Fig. 141. Twining or volubile stem of Calystegia sepium, great bindweed. It turns from right to left of a person supposed to be standing in the axis of the plant.

Fig. 142. Twining stem of Humulus Lupulus, the Hop. It turns from right to left of a person supposed to be standing in the axis of the plant.

bushes. The limits between these different kinds of stem are not always well defined; and there are some plants occupying an intermediate position between shrubs and trees, to which the name of arborescent shrubs is occasionally given. The usual name given to the herbaceous stem is *Caulis;* in grasses the stalk is called a *Culm* (Fig. 78, p. 33); while in Palms (Fig. 83, p. 37), and Tree Ferns (Fig. 165, p. 70), the stem is denominated *Caudex* and *Stipe.*

88. Stems assume anomalous forms. In the Tortoise, or Elephant's-foot plant, the stem forms a large irregular thick mass, with a rough and tuberculated exterior. In the Melon-Cactus (Fig. 88, p. 38), it is globular, in other species of Cactus (Fig. 43, p. 22), it is jointed, columnar, or angular; while in the many Orchids (Fig. 143), it assumes an oval or rounded form, and is called a *Pseudo-bulb.* The stem is so short in some plants, as the Primrose, Cowslip (Fig. 144), Gentian, and Dandelion, that they are called *stemless* or *acaulescent.* A similar term is given in ordinary language to plants whose stems are buried in the soil, such as Cyclamen or Sow-bread.

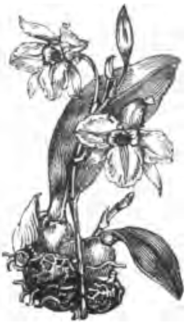

Fig. 143.

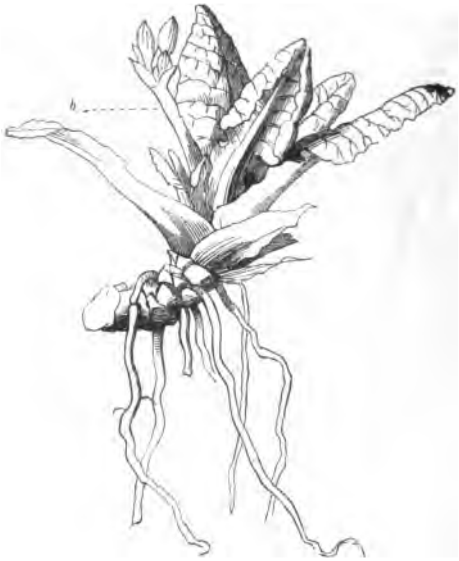

Fig. 144.

89. The stem, although it has a tendency to rise upwards when first developed, in many instances becomes prostrate, and either lies along the ground, partially covered by the soil, or runs completely

Fig. 143. An Epiphytic Orchid (*Maxillaria*), producing thickened stems, called Pseudo-bulbs, as seen at the lower part of the figure. These Orchids are attached to stems of trees, and send out aerial roots.

Fig. 144. Cowslip (*Primula veris*), having the stem short and thick, and partially under ground. The leaves are called radical, because they arise from the crown of the root. Roots are seen coming off from the thickened stem. The flowering stalk in the state of bud, is seen at *b.*

underneath its surface, giving off roots from one side, and buds from the other. Some stems are therefore subterranean, and are distinguished from roots by the provision made for regular leaf-buds.

90. The points where leaves or leaf-buds are produced, are called *nodes*. In certain jointed stems or branches, as the Bamboo, these are well marked; but in stems which are not articulated, the nodes are often distinguished chiefly by the leaves which they bear, or by the scars left after their fall. The intervals between the nodes are denominated *internodes*, and they are of different lengths, according to the distance at which the leaves are placed from each other.

91. The stem may be considered as formed of a series of leaves, at first closely aggregated on a shortened axis, and afterwards separated by more or less evident intervals. As the leaves decay and fall off, the stem becomes more conspicuous and uninterrupted. Buds may be regarded as shortened leaf-bearing axes, capable of elongation, so as to form stems and branches, with nodes and internodes. Some buds are terminal (Fig. 145, *a*), or are produced at the extremity of the primary axis, just as the first bud in the Embryo-plant. These buds in their after-growth continue to add to the length of the stem. Other buds are lateral (Fig. 146, *b*), or are produced on the sides of the axis. These are concerned in the production of branches.

92. In trees which do not ramify, as most palms, there are no lateral buds. In plants which have permanent stems, and in which the leaves are deciduous, provision is made for subsequent growth, by the production of buds which lie dormant during the winter, or the season of repose, and are ready to burst forth when the spring or the rainy season returns. The buds are situated at the angles where the leaves join the stem, as in Figures 145 and 146, where *b b b* indicate the scars of fallen leaves, in the *axil* of which, or, in other words, at the angles formed between them and the stem, buds are produced. In cold and temperate climates these buds are protected by a coarse external scaly covering (Fig. 145, *a*), and sometimes also by a waxy, glutinous, or resinous matter, as is well seen in the Horse-chesnut.

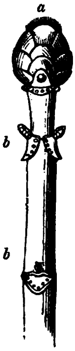

Fig. 145.

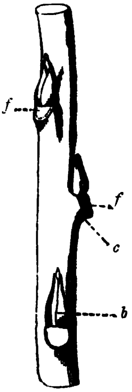

Fig. 146.

93. Buds, in place of producing branches, are, in some instances, abortive, or remain latent, ready to be developed when any injury has been inflicted on the terminal buds or branches. Occasionally, after a

Fig. 145. Stem ending in a terminal bud, *a*, covered with protecting scales, which have a spiral arrangement, and are thrown off when the proper leaves are developed. This terminal bud continues the stem in an upward direction. Lateral buds are seen at *b b*, which are produced in the axil of leaves which have fallen, leaving scars or cicatriculæ. The points in these scars mark the bundles of vessels which proceeded to the leaves.

Fig. 146. Branch of Glycine, shewing lateral buds, *b*, produced in the axils of leaves, *c*, or at the points where the leaves join the axis. The leaves have fallen, and left cicatrices or scars. In the scars the fibrous bundles of vessels, *f f*, are seen.

partial development as branches, buds are arrested and form knots or nodules. The embryo-buds or nodules of the Beech, Cedar, and Olive, are apparently of this nature.* Sometimes several buds unite together in the axil of a leaf, and form a peculiar flattened branch.

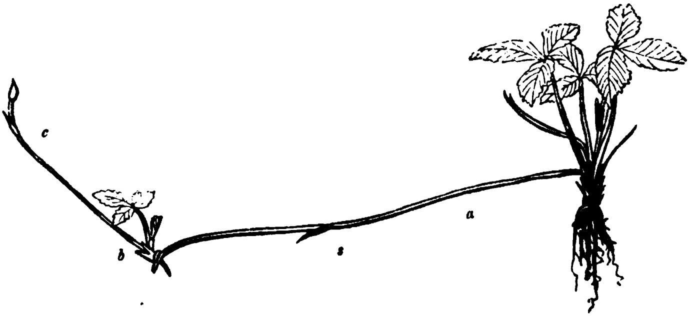

Fig. 147.

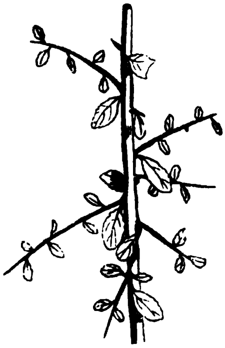

Fig. 148.

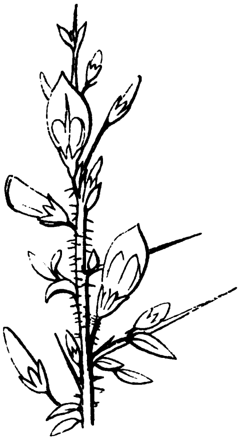

Fig. 149.

Fig. 147. Runner, *a*, or flagellum of strawberry (*Fragaria vesca*). The runner is a slender branch, bearing at intervals leaf-buds, *b*, which form separate plants, and which are capable of forming other runners, *c*. The scales, *s*, on the runner, *a*, are small leaves capable of giving off branches.

Fig. 148. Branch of the Sloe (*Prunus spinosa*), producing spines or thorns, which are abortive branches, as shewn by their bearing leaves.

Fig. 149. Ononis spinosa, a spiny or spinescent plant. Leaves are produced on one of the spines or thorns. Some consider it as the Kotz or Koz of the Scripture, which is translated thorns (Gen. iii. 18; Hosea x. 8). The plant is called Spiny rest-harrow, and is said to be common in Palestine, as well as in many parts of Europe.

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* Nodules, as they occur in the Cedar of Lebanon, have been shewn to be of the nature of buds; so also in the Olive, where, under the name of Uovoli, they are used for propagating the plant. Lindley says, that specimens he has received of these peculiar knots from Prince of Wales Island, fully confirm the view of their being capable of forming branches. Bird's-eye maple is said to be the timber cut from maple trees affected with these excrescences. The Bruscum of the Romans, so much prized by their cabinet-makers, was the wood of the common maple, twisted into irregular forms, in consequence of the presence of such excrescences.

94. Branches are sometimes long and slender, and run along the ground, producing roots and leaves at their extremity or apex. This is seen in the *runner* (flagellum) of the Strawberry (Fig. 147, *a*). In the Houseleek (Sempervivum) there is a similar prostrate branch of a shorter and thicker nature, producing a bud at its extremity capable of independent existence. It receives the name of *offset* (propagulum). A *stolon* differs from these in being a branch which curves towards the ground, and, when reaching a moist spot, takes root and forms an upright stem, and ultimately a separate plant. It is a sort of natural layering, and the plant producing such branches is called *stoloniferous*.

95. Spines or thorns are usually abortive branches ending in sharp points. This is shown by their producing leaves occasionally (Figs. 148, 149), and by their being frequently changed into ordinary branches during cultivation. Plants bearing thorns (modifications of branches or leaves) are denominated spiny, spinose, or *spinescent*. Such plants may be illustrated by the species of Zizyphus, which abound in the warm, dry, and uncultivated parts of the East, and which, while they choke vegetation, present great obstacles to travellers. In Figures 150 and 151 are represented two species, Zizyphus Spina

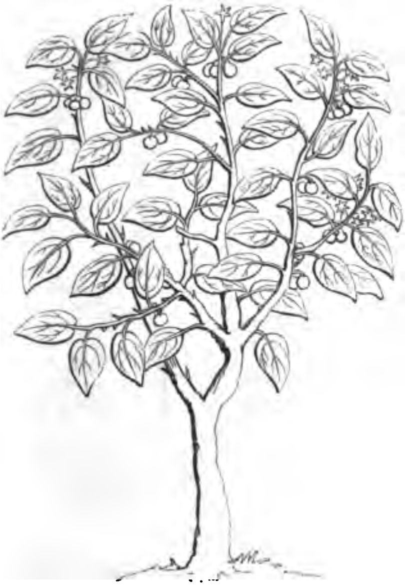


Fig. 150.

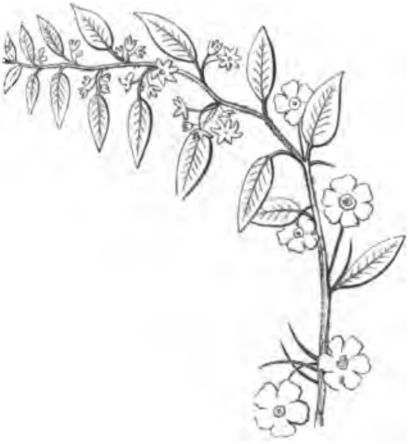


Fig. 151.

Fig. 150. Zizyphus Spina Christi, a thorny tree of Palestine, which by some is considered to be the Akantha of the New Testament, mentioned in Matthew vii. 16; xiii. 7, 22; xxvii. 29, and in the parallel passages of Mark and Luke, as well as in John xix. 2, 5.

Fig. 151. Zizyphus Paliurus, or Paliurus aculeatus, another thorny plant of Palestine, supposed to be the Hebrew Shamir, translated briars in Isaiah v. 6; vii. 23, 24, 25; ix. 18; x. 17; xxvii. 4; xxxii. 13.

Christi and Zizyphus Paliurus, which are interesting as connected with Scripture history. *Tendrils* (cirrhi) are frequently an altered state of leaf-buds or branches, as in the Passion-flower and the Vine (Fig. 152), enabling the plants to climb. In the Vine, as represented in Figure 153, the tendrils, *v v v*, are considered by some as the terminations of separate axes. The lowest leaf in the figure is connected with the first axis, which ends in a spiral tendril, *v;* and between this tendril and the leaf a bud is given off, forming a second axis, which ends in the second tendril, *v;* between which and this second axis another bud is given off, forming a third axis, ending in a third tendril, *v*, and so on. The different axes are in this case called *cirrhose*.

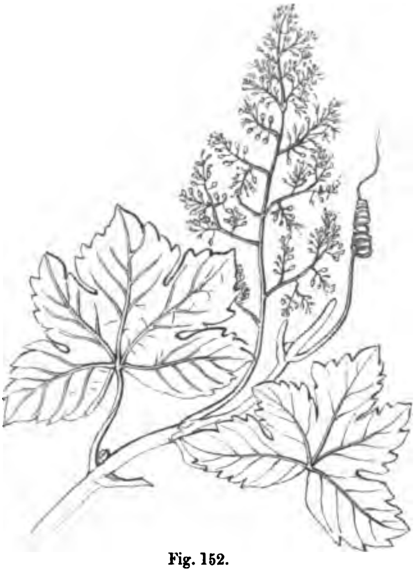


Fig. 152.

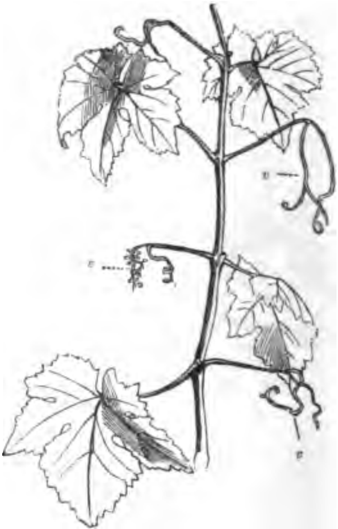


Fig. 153.

96. *Subterranean stems* and *branches* are sometimes short and thick, at other times they are elongated. Some are completely under ground, while others are only partially so; some increase by lateral, others by terminal buds. Many of them are in ordinary language called roots, from which, however, they are distinguished by the power of forming regular buds, or by having rudimentary leaves or scales on their surface. Many of them contain much nourishing matter, which is stored up for the future growth of the plant.

97. *Rhizome*, or root-stock, is the name given to certain root-like forms of creeping stems, which are more or less completely subter-

Fig. 152. The Vine (*Vitis vinifera*), the Gephen of the Old Testament, shewing the leaves with radiating venation, the clusters of flowers, and the tendril or cirrhus coiled up in a spiral form.

Fig. 153. Part of the stem of the Vine, shewing the formation of tendrils, each of which are considered as terminating axes. Between each leaf and tendril a bud is given off which forms an axis ending in a tendril, *v*. The axes are all cirrhose.

ranean. They are seen in Iris (Fig. 154), in Ginger (Fig. 155), and Convallaria (Fig. 156). Such stems exhibit on their upper surface the marks or scars of leaves, and it is to the scale-like appearance of these markings that the plant called Solomon's seal (Fig. 156), owes its name. Of a similar nature is the *Soboles*, or creeping stem of Carices (Fig. 157), Papyrus (Fig. 26, p. 20), and other grass-like plants, which spread through the sand and loose mud in such a way as to bind the particles together.

98. In the Banana (Fig. 64, p. 28), there is an underground stem which sends up shoots or branches of a herbaceous nature to bear the flowers and the fruit. In Asparagus the shoot developed from the subterranean stem is called a *Turio;* it is the part used as an article of diet; at first it is covered with scales, but it afterwards gives off branches, which bear leaves, flowers, and fruit. In the Rose and Mint a subterranean branch arises from the stem, which runs horizontally to a certain extent, and ultimately sends up an aerial stem, which becomes an independent plant. Such branches are denominated *Suckers*, and the plants are called *Surculose.* The gardener divides the connection

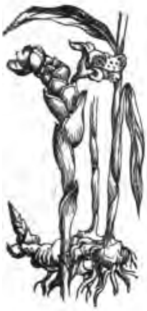


Fig. 155.

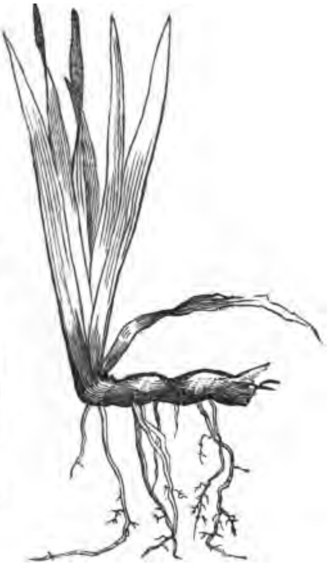


Fig. 154.

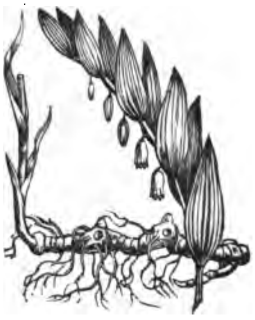


Fig. 156.

Fig. 154. Rhizome, or partially subterranean stem of Iris, giving off ensiform or sword-like leaves at one part, and roots from the lower surface.

Fig. 155. Rhizome, or thickened creeping stem of Ginger (*Zingiber officinale*), producing flowering stems and roots. This rhizome or root-stock is the part used economically and medicinally.

Fig. 156. Rhizome, root-stock, or partially subterranean creeping stem of Solomon's-seal (*Polygonatum multiflorum*). The scars left on the stem by the fall of the buds, give rise to the English name of the plant.

between the sucker and the parent stem, in order to propagate these plants.

99. The *Tuber* is a subterranean branch, which is arrested in its growth, and becomes remarkably thickened, in place of being elongated. It is seen in the potato and Jerusalem Artichoke; and the *eyes* produced in these instances are true leaf-buds. When the older parts die away, these tubers are found to belong to *one* axis with the new structures, which are subsequently formed. In the Arum (Fig. 158), Colchicum (Fig. 159), and Crocus (Figs. 160, 161), the tubers are perfected after the other parts, which belong to the same axis with themselves, so that they and the new structures belong to two axes, or at least to two different processes or shoots of the same axis. Such tubers are called *Corms*. They have a central axis, which is sometimes covered by thin scales, and they may be looked upon as shortened axes with scaly leaves, or as subterranean buds. Corms may be regarded as dilated stems intervening between the first buds and the roots. They occur in monocotyledonous plants. Corms give off buds in the form of young corms. In the Crocus (Fig. 161), these are produced successively near the apex of the old corms, which are gradually absorbed. Thus, in Figure 161, No. 1 indicates the original corm now decayed; 2, the corm or bud produced from it; and, 3, the young bud produced from No. 2, and connected with the flowering stem of the year. In Gladiolus, the new corms are so superimposed

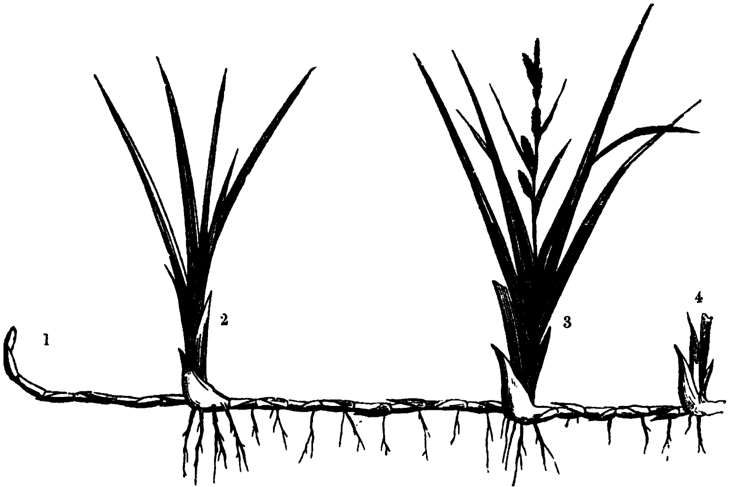


Fig. 157.

Fig. 157. Carex arenaria, sand carex, shewing a creeping subterranean stem, soboles. The bud marked 1 remains subterranean during the first year. It sends off a creeping branch or stem ending the second year in another bud, 2, which developes leaves and roots. In the same way this produces a stem ending in the bud 3, producing leaves, flowers, and roots. In its turn, 3 gives off a stem ending in a bud, 4. This Carex is one of those which binds the loose sands of the sea-shore together.

upon each other, that they gradually rise above ground. In Colchicum (Fig. 159,) the new corm, *b*, is produced alternately at either side of the old one, *a*, which shrivels. Sometimes three generations may be seen at the same time—the old corm, the new corm, and the bud of next year.

100. The *Bulb* is also a short subterranean axis, which is covered with fleshy scales containing succulent cells. It is a bud produced under ground, the centre corresponding to the axis, which is clothed with scales, and which sends flowering stems upwards, and roots downwards. In the Lily (Fig. 162), the thick and narrow scales

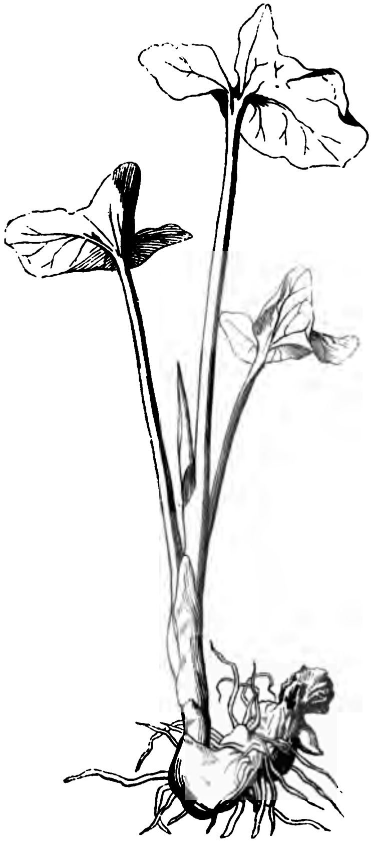


Fig. 158.

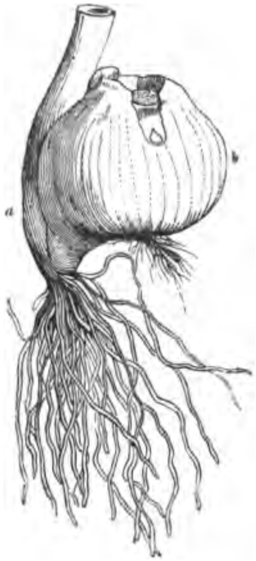


Fig. 159.

Fig. 158. Corm, or underground stem of Cuckow-pint (*Arum maculatum*), a Monocotyledonous plant. The Corm produces leaf-buds at one part, and roots at another. It contains much starch, which, when washed, yields Portland Sago.

Fig. 159. Corms of Meadow-saffron (*Colchicum autumnale*); *a*, old corm shrivelling; *b*, young corm produced laterally from the old one. Leaf-buds are produced at the upper part; roots below.

are arranged separately in rows, and the bulb is called *scaly;* while in the Leek (Fig. 164), the scales are broad, and enclose each other

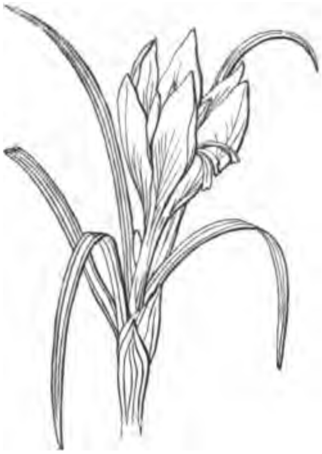
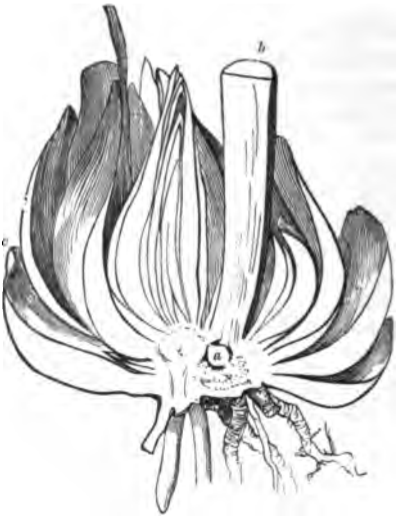


Fig. 160.



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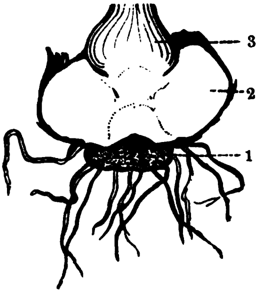

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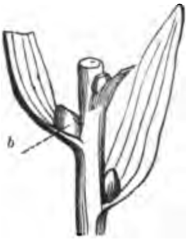

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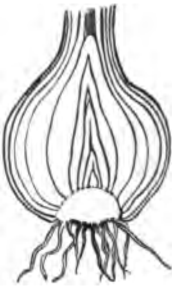

Fig. 164.

Fig. 160. The flower of the Saffron-plant (*Crocus sativus*), the corms of which are seen in Fig. 161. The plant is the Karcom of the Bible, mentioned in Cant. iv. 14; and is the Krokos of the Septuagint.

Fig. 161. Corm of the Saffron (*Crocus sativus*), shewing the mode in which new corms are produced above the old. It may be looked upon as a rhizome, increasing vertically in place of horizontally. No. 1 indicates the old corm now shrivelled; 2, the corm produced at the apex of it, in the form of a bud; 3, the young bud producing a flowering stem.

Fig. 162. Bulb, or underground bud of the Lily, consisting of numerous fleshy scales arising from a common shortened axis, *a*, and covering a growing point, *b*. From the axis roots are given off below. It is denominated a Scaly, or naked bulb, and the axis is in the form of a fleshy plateau or disc, which gives origin to roots and scales; *c*, lateral buds or cloves, arising from the axil of scales; *b*, flowering stem proceeding upwards, covered at first by the scales.

Fig. 163. Stem of bulbiferous Lily (*Lilium bulbiferum*), shewing bulbels or bulblets, *b*, produced in the axils of the leaves. These bulblets are buds easily detached, and capable of forming independent plants.

Fig. 164. Tunicated bulb of Leek (*Allium Porrum*), cut perpendicularly, shewing the plateau or disc at the base whence roots proceed on one side, and scales with the growing point on the other. The outside scales are thin, while the internal ones are fleshy,

in a concentric manner, the outer ones being thin and membranous, and the bulb is *tunicated.* The scales are equivalent to leaves, and they produce buds in the form of cloves or young bulbs at the part where they join the axis. At the base of the bulbs there is a flattened rounded portion (Fig. 162, *a*), which produces roots from one side, and scales and leaves from the other. The central bud produces the flowering stem. The lateral buds or cloves sometimes remain attached to the axis, and produce flowering stems, so that the same bulb continues to flower for many years, as in the Hyacinth and Tulip; at other times the young bulbs are detached, and form separate plants. In the case of some plants, as Lilium bulbiferum (Fig. 163), bulbs are also produced on the stem, in the form of bulbels or bulblets, *b*, which are scaly buds, capable of being detached, and of forming independent plants.

101. Irmisch* considers bulbs and tubers, not independently, either as roots or buds on stems, but as bulbous and tuberous plants, and describes them as a special mode of persistence in plants. He divides them into three kinds: 1. A transformed thickened part, being the altered axial or stem-structure. This is called an axial or stem-tuber, as in the Potato, Arum, Colchicum, and Crocus. 2. Transformations of the root, called radical tubers, as in Orchis. 3. Transformation of leaves, or parts of leaves. These are called bulbs or leaf-tubers, as in the Onion, Lily, and Tulip.

2. INTERNAL STRUCTURE OF THE STEM IN GENERAL.

102. The forms of the stem having been considered, we now proceed to examine its anatomical structure. This structure consists of the elementary tissues combined and arranged in various ways. In some plants the part which serves the purpose of a stem, is composed entirely of cells arranged in the form of very narrow filaments, which are simple or branched, as in some fungi (Fig. 11, p. 11) and confervæ (Fig. 30, p. 20), or which form an expanded surface, called a Thallus or frond (Figs. 14 and 15, p. 12, and Fig. 50, p. 24). Such cellular plants have received the name of *Thallogens* or *Thallophytes;* while those producing stems composed both of vessels and cells, are sometimes called *Cormogens* or *Cormophytes.* In ordinary conspicuous stems, both cellular and vascular tissue are present. The latter is developed in a vertical manner, and is called the vertical or longitudinal system, while the former increases in every direction, and is called the horizontal system.

103. The arrangement and development of these two systems give rise to three marked forms of stems:—1. *Acrogenous*, in which the bundles of vessels are simultaneously developed, and the additions to the stem take place at the summit, by the union of the bases of the

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* Irmisch (Th.) Zur Morphologie der Monokotylischen Knollen-und-Zwiebelgewächse. Berlin, 8vo. 1850. See also translation in Botanical Gazette for 1851.

leaves. Plants having this kind of stem are called *Acrogens*, or summit-growers. Tree ferns (Fig. 165) furnish an example. 2. *Endogenous*, in which the bundles of vessels are definite, and are deposited towards the centre, which becomes filled up with them in the progress of growth, so that the diameter of the stem increases in a great mea-

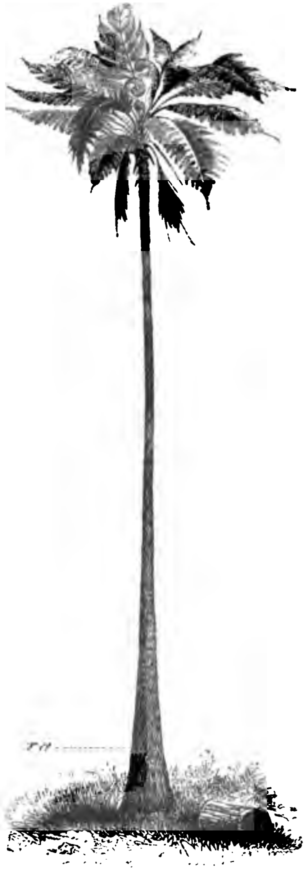

Fig. 165.

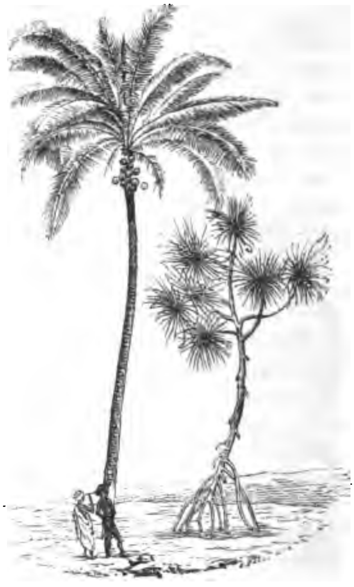

Fig. 166. Fig. 167.

Fig. 165. East Indian Tree Fern (*Alsophila perrotetiana*). It has an acrogenous stem, and its embryo is acotyledonous. The stem or stipe is unbranched. Towards the base, *r a*, there is an obvious enlargement caused by a number of adventitious or aerial roots which cover the stem, and are applied closely to it.

Fig. 166. Coco-nut Palm (*Cocos nucifera*). It has an endogenous stem, and its embryo is monocotyledonous. The stem is unbranched, and bears a cluster of leaves and fruit at the summit.

Fig. 167. Screw-pine (*Pandanus odoratissimus*). It has an endogenous stem, and its embryo is monocotyledonous. The stem is branched, and bears numerous clusters of leaves, which are arranged in a remarkable spiral or cork-screw like manner. From the lower part of the stem numerous aerial roots arise.

sure by the new matter pushing out that previously formed. Such plants are called *Endogens*, or Inside-growers. Palms (Fig. 166) and Screw-pines (Fig. 167) supply examples. 3. *Exogenous*, in which the bundles of vessels are produced indefinitely in an outward direction, and the stem increases in diameter by the annual formation of a new layer of woody matter formed on the outside of the preceding layers. Such plants are called *Exogens*, or Outside-growers. Ordinary trees, such as the Scotch Fir (Fig. 51, p. 25), and the Oriental Plane tree (Fig. 168), furnish instances.

Fig. 168.

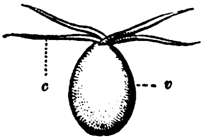

Fig. 169.

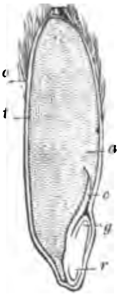

Fig. 170.

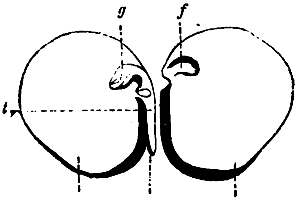

Fig. 171.

104. While the structure of the stem supplies obvious characters, it will be found that other distinguishing marks separate these three great classes of plants even in their earliest state. Thus, Acrogens have a cellular Embryo (Fig. 169), which

Fig. 168. The Plane-tree of the East (*Platanus orientalis*). It has an exogenous stem, and its embryo is dicotyledonous. The stem is branched. The tree seems to be the Armon of the Bible, and is mentioned under the name of Chesnut-tree in Gen. xxx. 37; Ezek. xxxi. 8.

Fig. 169. Spore, *v*, or cellular embryo of an acrogenous plant, with vibratile cilia, *c*. The embryo is acotyledonous, *i. e.*, has no seed-leaves or cotyledons.

Fig. 170. A vertical section of grain of oats, shewing the embryo plant at the lower part, consisting of *r*, the part whence the roots proceed; *g*, the young stem, and *c*, the single cotyledon. The plant is monocotyledonous. It has an endogenous stem. The covering of the grain is marked *o*, that of the seed *t*, and *a* is the nourishing matter called albumen. In Figure 114, p. 49, the single cotyledon, *c*, of maize, is represented when the embryo is sprouting.

Fig. 171. Embryo of the Pea, shewing the point whence the young root arises, *r*; the young stem or plumule, *g*; the stalk, *t*, connected with the cotyledons, *c c*, which are separated and laid open; *f*, the depression in which the plumule lay. The plant is dicotyledonous, and its stem is exogenous. In Figure 113, p. 49, the cotyledons, *c c*, of the haricot, are represented appearing above ground at the time when the embryo is sprouting.

has no cotyledons or seed-lobes—that is to say, has no leafy appendages to the Embryo or young plant, and hence they are called *Acotyledonous*. Endogens have an Embryo with one cotyledon on the axis, and when sprouting send up a single seed-leaf (Fig. 170 *c*); hence they are *Monocotyledonous*. While Exogens have two such cotyledons or seed-lobes (Fig. 171, *c c*), and are hence *Dicotyledonous*.

Thus, Acrogens are Acotyledonous.
Endogens are Monocotyledonous.
Exogens are Dicotyledonous.

A. *Exogenous Stem or the Stem of Dicotyledonous Plants.*

105. Exogens are the largest class of plants in all parts of the globe, and the structure of their stems is familiar to us in the trees of cold and temperate climates. In Britain the trees of our forests are all exogenous in their formation. Such trees, however, occur also in warm regions, associated with others exhibiting endogenous and acrogenous structures. Exogenous trees are illustrated in Figures 172-176, representing the Scotch Fir (Fig. 172), the Cork Oak (Fig. 173), the American Plane Tree (Fig. 174), the Cedar of Lebanon (Fig. 175), and the Baobab of Senegal (Fig. 176).

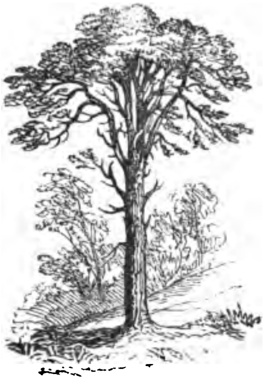

Fig. 172.

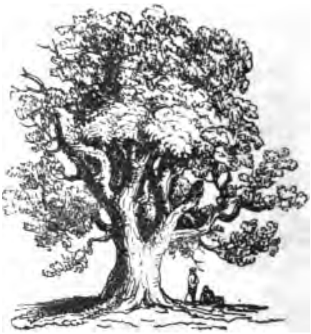

Fig. 173.

106. An exogenous stem, in its earliest condition, is entirely cellular. When the plant begins to grow and sends up its first leaves, the cellular tissue of the axis is seen to be traversed by bundles of vessels (vascular bundles), which soon divide the stem into two marked portions; an internal, forming the central pith or medulla, and an external, forming the cortical pith or bark, covered by epidermis. The

Fig. 172. Scotch Fir (*Pinus sylvestris*), an exogenous or dicotyledonous tree of the colder regions of the temperate zone.

Fig. 173. Cork-oak (*Quercus Suber*), an exogenous or dicotyledonous tree of the warmer regions of the temperate zone. Its outer layer of bark supplies cork.

connection between the central pith and cellular bark is kept up by means of lines of cellular tissue, called medullary rays, which are interposed between the vascular bundles. At the end of a year's growth,

Fig. 174.

Fig. 175.

Fig. 176.

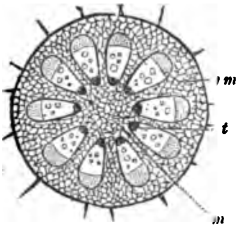

Fig. 177.

Fig. 174. American Plane (*Platanus occidentalis*), an exogenous tree of temperate regions.

Fig. 175. Cedar of Lebanon (*Cedrus Libani*), an exogenous or dicotyledonous tree of temperate regions. It is remarkable for its wide-spreading branches, and used to abound on Lebanon. It is the Eres or Æres of the Old Testament, and is alluded to in various passages in the books of Samuel, Kings, Chronicles, Psalms, &c.

Fig. 176. Baobab-tree, or Ethiopian Sour-gourd (*Adansonia digitata*), an exogenous tree of hot climates. It is found on the west coast of Africa, and on the Cape de Verde islands. Its trunk attains sometimes a circumference of ninety feet, but its height is moderate. Some Baobabs are reckoned to be of a very great age.

Fig. 177. Horizontal section of the stem of a melon, shewing exogenous structure of one year's growth. Pith, *m*, consisting of loose cells often hexagonal; *t*, tracheæ, or unrollable spiral vessels, forming the medullary sheath, which is interrupted at different points to allow medullary rays, *r m*, to pass from the pith to the bark. The medullary rays divide the stem into ten wedge-shaped vascular bundles, the outer part of the bundles forming the fibrous layer of bark, and the inner constituting the wood; the pitted vessels are represented by large round openings. The circumference is the outer portion of the bark, consisting of cells which are covered by the general integument bearing hairs.

we observe, in the exogenous stem, a central cellular pith, a circle of vascular bundles in the form of wedge-shaped masses, an external bark and integument, and rays passing from the pith to the bark. This is the complete structure of exogenous herbaceous stems, which die down annually. The appearance is exhibited in Figure 177, which is the young stem of a melon cut horizontally; *m* is the medulla or pith, composed of loose cells containing fluid; *t*, tracheæ or spiral vessels immediately surrounding it, and forming a medullary sheath; *r. m*, medullary rays, composed of more or less flattened cells, which extend from the pith to the external cellular bark or cortical layers; on the outside of the bark is the integument with projecting hairs, and between the medullary rays are ten wedges of fibro-vascular bundles, consisting of woody, porous, annular, reticulated, and spiral vessels; in these wedges the porous vessels are represented by large rounded openings. In Figure 178 is given a horizontal section of one of the fibro-vascular bundles, in order to shew its composition. The section extends from the pith to the outer integument; *m*, medulla or pith; *t*, tracheæ or spiral vessels, forming the sheath round the pith, the fibres being unrollable; *r m*, cellular medullary ray at the side of the vascular wedge; *f*, woody, annular, and reticulated vessels; *v p*, porous or pitted vessels of large calibre (Fig. 62, p. 26); *c*, a layer of green and active cells, forming what is called the cambium layer; *l*, woody fibres, constituting a layer called the inner bark (Fig. 45, p. 23); *v l*, ramifying laticiferous vessels (Fig. 70, p. 30); *p c*, cortical cells, constituting the cellular bark, which is covered by the common integument, *e*.

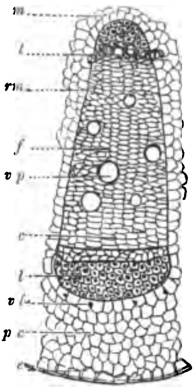

Fig. 178.

107. In stems which are not annual, the growth of the second year consists of a new formation of vascular bundles outside the previously formed layer, between it and the bark—the connection between the pith and the bark being still kept up by cellular rays. Between the pith and the bark there are annually formed a layer of active formative cells, called cambium cells, which are concerned in the development of new woody fibres. In Figure 179 is shewn a transverse section, *A*, and a vertical section, *B*, of one of the fibro-vascular bundles of the maple at the commencement of the second year of growth—the letters referring to both sections; *t*, tracheæ, or spiral vessels, forming the medullary sheath, which allows the medullary rays to pass through at different points; *v p*, porous or pitted vessels, constituting bothrenchyma or taphrenchyma, and presenting large rounded openings; *f*, *f*, fibres formed of fusiform tubes, the inner, *f*, marking the fibres form-

Fig. 178. One of the vascular wedges of the melon separated to shew its composition; *m*, medulla or pith; *t*, spiral vessels of medullary sheath; *r m*, medullary ray; *f*, woody fibres; *v p*, pitted vessels; *c*, cambium cells between wood and bark; *l*, inner bark, consisting of woody fibres, and called endophlœum; *v l*, laticiferous vessels; *p c*, cellular envelope of the bark; *e*, general integument.

ing the wood of the stem, and the outer, *f*, those which form the cortical fibres of the inner bark; *c*, cambium cells between the wood and bark; *p c*, *p c*, cortical polyhedral cells, often of a greenish colour, forming a cellular layer of bark; *s*, outer cellular layer of bark, composed of cubical or tabular colourless cells, often of a corky nature, and hence called suberous; this cortical layer is covered by the general integument. Thus, at the commencement of the second year's growth there is a distinct formation of cambium cells, by the action of which a new layer of wood, and a new layer of fibrous bark is formed, and these cambium cells, being in connection with the medullary rays, keep up the connection between the medullary and cortical cells.

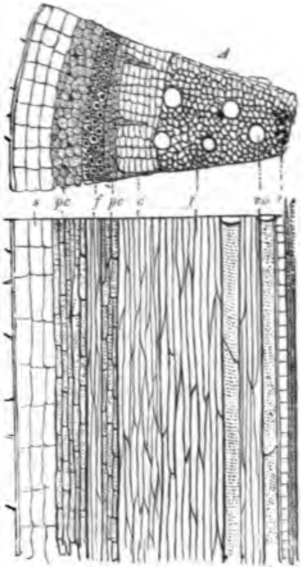

Fig. 179.

108. Let us now trace the changes which take place in the permanent woody stem of the Maple, after three years' growth, as represented in Figure 180. The yearly growth of the woody bundles is marked by the Figures 1, 2, 3:—1. The Pith, *m*, is surrounded by tracheæ, *t*, which are not repeated in the growths of subsequent years; outside these are the pitted vessels, *v*, and fibrous tissue, *f*, of the first year's growth. 2. Pitted vessels, *v*, and *f*, fibres, or woody and other vessels of the second year's growth. 3. Pitted vessels, *v*, along with fibres, *f*, of third year; *c*, layer of cambium cells outside the wood of third year. The outer part of the section consists of the layers of bark; *s*, the suberous, or outer layer of bark cells; immediately within, is *p*, cellular layer, and *l l*, fibrous layer of bark of first year; then follows the bark of the second year, *p l;* and, finally, the cortical layers of the third year, *p l*, which are separated from the wood by a cortical layer of new cells, *m c*, and the cambium layer, *c*.

109. In examining, therefore, the growth of an Exogenous stem, it will be seen, that while additions are yearly made to the layers of wood in an outward direction, so as to give rise to the term Exogen, or outside grower, the bark, on the contrary, increases by annual additions on the inside. The increase of the diameter of such stems takes place by successive deposits of vascular wedges in concentric circles,

Fig. 179. Section of the stem of a maple at the commencement of its second year's growth. *A*, Horizontal section; *B*, Vertical section. Spiral vessels round the pith *t*, pitted vessels *v p*, and woody fibres *f*, forming the layer of wood of the first year; *c*, cambium cells formed between wood and bark in second year's growth; *p c*, *p c*, cellular layer of bark with fibres, *f*, constituting the inner bark (liber or Endophlœum); *s*, suberous layer of bark (Epiphlœum), seen in the second year's growth as distinct from the cellular layer below; on the outside of the suberous layer is the general integument, with projecting hairs.

year after year, and during this growth the bark will become gradually distended. On examining old stems the different annual layers can be counted, especially in trees of cold and temperate climates, where there is a marked cessation of growth during winter. The parts of an Exogenous stem of three year's growth are displayed in a diagramatic manner in Figure 181—A being a horizontal, and B a vertical section of part of the stem. The cells of pith of an hexagonal form are marked *a a;* the pitted vessels, with large openings placed towards the inner part of each year's circle, *b b b;* the woody fibres of successive annual layers, *c c c;* spiral vessels of the medullary sheath, *d;* cambium layer of cells, *e;* inner fibrous bark, *f;* cellular cortical envelope, *g;* outer suberous layer of bark, *h;* medullary ray, *i i;* the figures 1, 2, and 3, indicating the growth of the different years.

110. Let us now proceed to examine the different parts of an Exogenous stem proceeding from the centre to the circumference. The *Pith* (Fig. 181, *a*), consists of cellular tissue (parenchyma), at first succulent, but afterwards becoming dry, as its juices are absorbed for the use of the young plant. In the progress of growth its cells are sometimes broken up, so as to form large empty cavities, as in the Walnut, Poke, Jessamine, and Horse-chesnut; at other times the whole pith gives way, owing to the rapid distension of the outer part of the axis in its early state, and then the stem becomes hollow, with shreds of pith attached to its interior, as in Umbelliferæ and Grasses. The cells of pith are well seen under the microscope, in the Elder, Papyrus (Fig. 26, p. 20), and Rice-paper.* The *Medullary Sheath* is the first

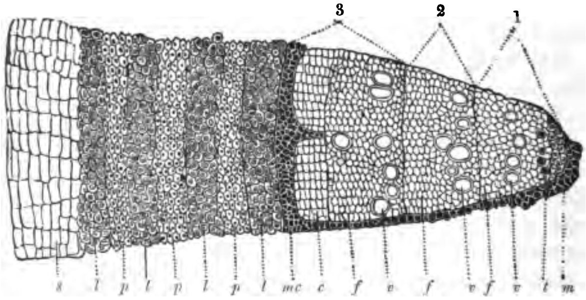

Fig. 180.

Fig. 180. Horizontal section of one of the vascular wedges of the maple, taken from a stem three years old. During the first year—1, there exist, *m*, medulla or pith; *t*, spiral vessels round pith, and, outside of these, pitted vessels, *v*, with large round openings, and woody fibres, *f*. In the second year—2, pitted vessels, *v*, and woody fibres, *f*. In third year—3, pitted vessels, *v*, along with woody fibres, *f*. During this third year the cambium layer of cells, *c*, is formed, on the outside of which are the layers of bark. The suberous layer of bark (Epiphlœum), consisting of tabular and cubical cells, is marked *s*, within this is seen the cortical layer of the first year, *l*, *p*, *l*, consisting of cells, *p*, and fibres, *l*, then that of the second year, *p*, *l*, and then that of the third year, *p*, *l*; *mc* being the bark in the progress of formation, next to the cambium layer, *c*.

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* For remarks on Pith, see Guillard, sur la moelle des plantes ligneuses. Ann des Sc. Nat. 3 ser. Botan. t viii. 295.

formed vascular layer (Fig. 181, *d*). It consists principally of spiral vessels (Fig. 63, p. 27), the fibres of which can be uncoiled. This is the only part of an exogenous stem in which these vessels ordinarily occur. This medullary circle is not always complete, spaces being left between the vessels where the medullary rays and the pith communicate. The tracheæ traverse the cellular tissue so as to reach the leaves.

111. *The Wood.*—The layers of wood (Fig. 181, *b c*), are formed outside the medullary sheath (Fig. 181, *d*). They consist of woody fibres (prosenchymatous tubes) such as those represented in Figure 45, p. 23, mixed with dotted ducts (Figs. 61 and 62, p. 26), and occasionally with a few annular (Fig. 66, p. 28) and reticulated (Fig. 67, p. 28) vessels belonging to the spiral type. On making a transverse section of the stem of the Chesnut, Ash, or Oak (Fig. 182), the extremities of the dotted ducts (pitted vessels) will be seen in the form of large rounded openings on the inner side of the woody circle or zone. In Figure 182 they are represented as dark points on the inner margin of each circle. In the Maple (Figs. 179, 180), Plane, Lime, and Hornbeam, the openings are not so large, and are diffused through-

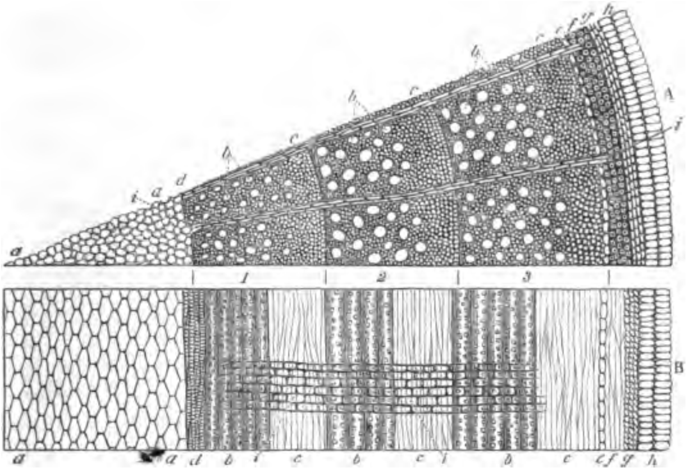

Fig. 181.

Fig. 181. Diagram of the structure of an Exogenous or Dicotyledonous stem of three years' growth, A being a transverse section, and B a vertical section. This is taken from the third edition of Dr. Carpenter's valuable work on Physiology. The Figures 1, 2, 3, mark the years of growth, and the letters refer to the same parts in both figures; *a a*, medulla or pith, consisting of hexagonal cellular tissue; *b b b*, pitted or dotted vessels (Bothrenchyma, and Taphrenchyma), and *c c c*, woody fibre of successive annual layers; *d*, spiral vessels of the medullary sheath; *e*, layer of cambium cells between wood and bark; *f*, inner fibrous layer of bark (Liber, Endophlœum); *g*, cellular envelope, forming middle layer of bark (Mesophlœum); *h*, outer corky layer of bark (Epiphlœum); *i i*, medullary ray which, in the transverse section, is seen running continuously from the pith to the bark; but in the vertical section, B, is seen interrupted, owing to the slight flexure which usually occurs, and which generally prevents us from tracing the ray in a continuous straight line when the stem is cut longitudinally.

out the annual zones, mixed with pleurenchyma. In coniferous (cone-bearing) plants, as the Fir and Pine, the woody layers are composed of disc-bearing pleurenchyma (Figs. 52-58, pp. 25, 26), without any dotted ducts, and hence, under the microscope, no large rounded openings are seen in the woody layers. This is represented in Figure 183, where the two rounded openings are not the extremities of dotted ducts, but lacunæ or cavities containing resin.

112. In the young state the pleurenchymatous tubes of the woody zones are pervious, but by degrees they are obliterated by the deposits of ligneous matter (lignin). In old exogenous trees the central wood is hard and durable, constituting the *Heart-wood* or *Duramen*, while the exterior wood is soft, forming the *Sap-wood* or *Alburnum*. The lignin deposited in the heart-wood frequently acquires a marked colour, as in the Ebony tree, where it is black; in the Black Walnut, where it is dark brown; in the Barberry and Judas-tree, where it is yellow; in the Red Cedar, where it is purplish-red; and in the Guaiac tree, where it is greenish.

113. The relative proportion between alburnum and duramen varies in different trees. Those in which the hard wood predominates are best fitted for building, and for withstanding the effects of moisture, dry rot, and the attacks of insects and other animals. The durability of woods depends on the nature of the ligneous matter deposited in their pleurenchyma, and this varies much. The following are the particulars given in the Nautical Magazine of experiments made on several kinds of wood 1½ inches square and 2 feet long, placed vertically in the ground, and about 1 foot 6 inches exposed to the atmosphere, on the 1st January 1831; examined at two different times, viz., 8th May 1833 and 24th February 1836:—

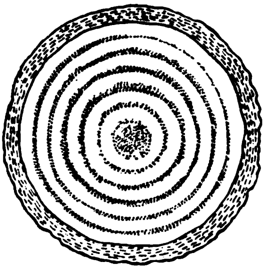

Fig. 182.

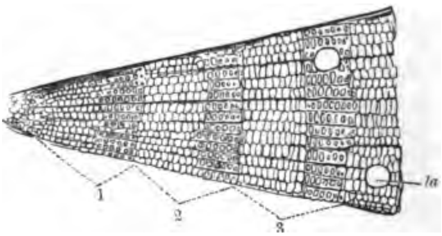

Fig. 183.

Fig. 182. Transverse section of the stem of an Oak, shewing the pith in the centre; the woody layers formed in concentric circles around it, and the layers of bark on the outside. There are six woody circles, indicating that the stem is the growth of six years, and the same age is indicated by the cortical layers. The dark dots on the inner side of the different woody layers mark the situation of the dotted vessels.

Fig. 183. Transverse section of the stem of a Fir three years old, as indicated by the Figures 1, 2, 3, which mark the annual layers of wood. In this plant there are no large openings of dotted ducts seen. The woody circles are made up chiefly of disc-bearing woody tissue. The two large rounded openings, one of which is marked *la*, are lacunæ, or cavities containing resinous matter, such as abound in the fir tribe.

WOOD.	8TH MAY 1833.	24TH FEBRUARY 1836.
Teak, East Indian	Very good	Rather soft, but good.
Teak, African	Very good	A little decayed.
Oak, English	Much decayed	Very much decayed.
Oak, Italian	Good, but decay had commenced in surface	Very much decayed.
Oak, Canada, White	Very much decayed	Very bad, and rotten.
Oak, Memel	Very much decayed	Very bad, and rotten.
Oak, Dantzic	Very much decayed	Very bad, and rotten.
Mahogany	Good	Tolerably good.
Fir, Dantzic	Much decayed	Very much decayed, and rotten.
Fir, Riga	Much decayed	Do.
Fir, Memel	Much decayed	Do.
Larch, Polish	Decayed $\frac{1}{4}$ in the surface	Decayed $\frac{1}{4}$ of an inch.
Larch, Scotch, Treenails	Surface $\frac{1}{4}$ inch decayed and brittle.	Surface $\frac{1}{2}$ inch decayed, the rest brittle.
Elm, English	Very rotten	All rotten.
Ash, American	Very rotten	All rotten.

In making experiments as to the durability of timber for lighthouse purposes, Mr. Robert Stevenson sunk various kinds of wood into the sea, and he found that teak was the best for resisting the attacks of the Limnoria terebrans.

114. The woody zones annually formed are not always of the same size. Much depends on the state of the climate and season, the exposure of the plant to air and light, and the nourishment which it receives. A narrow ring of wood may be considered as recording a cold season, while a wide one indicates a warm season. The thickness of the layers of the Scotch Fir is small as we approach the Poles. Between 50° and 60° N. latitude, it is difficult, according to Bravais and Martins, to find annual layers of a thickness less than one-third of a millimeter; in the north, on the contrary, the thickness is not $\frac{1}{18}$ of a millimeter.* The same zone also varies in size at different parts, so that, in many cases, the pith is excentric—that is, not exactly in the centre of the stem, owing to the circles being thicker on one side than on the other. Bravais and Martins notice a Scotch Fir in which the two semidiameters of the stem were to each at nine to nineteen, or the one more than double the other. In such cases, it usually happens, that the side of the tree having the greatest thickness is that which has been best exposed to air and light.

115. From the mode in which layer after layer of wood is formed, it follows that the age of an exogenous tree may be estimated by

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* See Bravais and Martins' Observations in Annales des Sciences Nat. 2 ser. t. xix. p. 129.

counting the number of woody circles. In trees of cool climates, where there is a marked cessation of growth, this may be done with tolerable accuracy up to a certain age at least; but in trees of warm climates, where there is a less marked period of repose, this cannot always be done accurately. It is said that in some of the trees of tropical America monthly circles are formed; while in species of Cactus and Cycas more than one year is required to form a single zone. In estimating the age of trees in temperate climates, the rings or zones of woody matter must be counted from the pith to the bark. Mistakes have been committed, in many instances, by merely making a section of a stem, embracing a few zones, and then estimating from their size for the whole diameter of the tree. This is well illustrated by Lindley in the case of the following specimens of foreign wood, in which the semi-diameters of the stem are different :—

	Semi-diameter A.	Semi-diameter B.	Total Diameter.	Real Age or No. of Zones.
Benthamia fragifera	9 Lines.	36 Lines.	45 Lines.	40
Pyrus foliolosa .	8 Lines.	22 Lines.	30 Lines.	36
Magnolia insignis .	11 Lines.	20 Lines.	31 Lines.	17
Alnus nepalensis .	11 Lines.	23 Lines.	34 Lines.	8

In the first of these woods, if a portion of the semi-diameter A were examined, we would find that each zone was 0·225 of a line deep, and as the whole diameter of the stem is 45 lines, we would estimate the side examined to be 22·5 lines deep. Hence we would conclude, that as the plant took one year to grow 0·225 of a line, it would be 100 years in growing 22·5 lines, while in fact it was only 40 years. In the same way, any calculation founded on a section taken from one side of the other woods mentioned, would be far from the truth.

116. A simple way, according to De Candolle, of estimating the age of a tree, is to make two notches on opposite sides of a tree, and ascertain the mean of the number of the annual layers. Suppose two inches in depth thus extracted, and that the one has 10 annual rings, while the other has 16, it is evident that the average rate of growth will be 13 rings per inch. If we then ascertain the diameter of the tree, deduct the thickness of the bark, and multiply one-half the remaining diameter by 13, we shall have a close approach to the true age of the tree.[*]

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[*] De Candolle, in his Physiologie Végétale, gives the following formulæ, by Otto, for measuring trees. Ascertain the diameter at the height of about five feet, and make a notch at the same point on the circular surface, to count a certain number of annual layers which we measure. We then find the annual growth of those trees which have left off growing in height, by the formula $\frac{4\,d\,(D-d)\,V}{n\,d^2}$; and for those which continue to grow in height by the formula, $\frac{D^3-(D-2\,d)^3\,V}{n\,D^3}$. D being the diameter of tree; V, volume of same; d, thickness of annual layers which have been counted; n, the

117. The following is given by De Candolle as the general rate of growth of the woody layers in different trees :—

	First Year.		Second Year.		Third Year.	
	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.
Oak, circumference . .	0	10½	0	11½	1	0½
Larch, do. . . .	1	0½	1	3	1	4
Elm, do. . . .	2	7½	2	9	2	11
Lombardy Poplar, do. .	1	8	2	0	2	3¾
Lime, do. . . .	1	8½	1	10¾	2	0

De Candolle states that the rate of the formation of timber diminishes rapidly after a given period, varying with the species. In the Oak the vigour of growth appears to diminish after 60 years, in the Larch after 40, in the Elm after 50, in the Beech after 30, in the Spruce Fir after 40, and in the Yew after 60 years. These statements, however, still require confirmation.

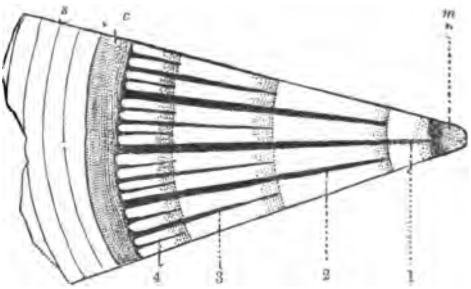

Fig. 184.

Fig. 184. Transverse section of part of the stem of the Cork Oak (*Quercus Suber*). The outer corky layer of bark (Epiphlœum), *s*, is very thick; *c* is the inner cellular envelope (Mesophlœum); immediately below it, is the liber, inner bark (Endophlœum), succeeded by woody circles, and then by the pith, *m*. Medullary rays are seen traversing the woody layers—one of these, 1, is complete, proceeding from the pith to the bark; the others, 2, 3, 4, are incomplete, proceeding only through some of the woody layers, and not reaching the pith.

118. *Medullary Rays.* These connect the pith and the bark (Fig. 184, 1). They consist of flattened quadrangular cellular tissue, having an appearance like bricks in a wall, and

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number of these layers. These formulæ depend on two theorems :—1. That cones or cylinders of the same altitude are to one another as the squares of their diameters. 2. That similar cones or cylinders are to one another as the cubes of their diameters. In fact, calling *n* the number of layers, whose volume is C, we have two propositions, viz. :—$V : C :: D^2 : D^2—(D—2d)^2$, and $V : C :: D^3 : D^3—(D—2d)^3$. Whence we have $C = \frac{4d\,(D—d)\,V}{D^2}$, and $C = \frac{(D^3—(D—2d)^3)\,V}{D^3}$. Dividing this total growth of layers by *n*, we have the growth of one year.

The formulæ are correct if we admit, that during any ten or twenty years a tree does not acquire more or less wood than in an equal number of other years. But if the layers of growth, calculated every twenty years for about eighty years, are of equal thickness, the quotient will be too small, and in this case we must make use of the following formulæ :—

1. For trees which do not increase in height, we have $V : C :: D^2 : (D + 2d)^2—(D—2d)^2$; whence we have $C = \frac{8d \times V}{D}$, and the annual growth will be $\frac{8d \times V}{2nD} = \frac{4d \times V}{n\,d}$.

2. For trees which grow in height we have $V : C :: D_3 : (D+2d)^2—(D—2d)^3$, and the annual growth will be $C = \left(\frac{(D+2d)^3—(D—2d)}{2nD^3}\right)V$. Reducing this for convenience, when we work

hence called muriform (Fig. 181, *i i*, p. 77). In the young stem these rays are large (Fig. 177, *r m*, p. 73), while in the more advanced woody stem they are seen as lines only. They constitute the silver-grain so conspicuous in maple, and they give the peculiar silvery lustre to many woods when cut in the direction from the pith to the bark. These rays do not proceed in a continuous plane from the top to the bottom of the tree. They pass through the woody layers in such a way as to be interrupted in their course (Fig. 181, B, *i i*, p. 77); and when a section is made perpendicularly to the rays, or, in other words, as a tangent to the circumference of the stem, their ends are seen projecting irregularly through the woody fibres. They are said by some authors to represent the horizontal system of the stem, or, as it were, the woof, which is traversed by the vertical woody bundles, like the warp. The medullary rays are in some cases, as in Clematis and Aristolochia, large and broad, while the woody wedges are comparatively small. Besides complete medullary rays, there exist others which only extend partially through the stem. This is represented in the horizontal section of a part of the stem of the cork oak, Figure 184. From the pith, *m*, to the cellular portion of the bark, *c*, the cellular line 1 extends completely, constituting a perfect medullary ray; but other minor rays marked 2, 3, 4, are seen extending only partially through the stem, and dividing the woody bundles into a different number of wedges at different parts.

119. *Cambium Layer.*—This is a layer of nucleated cells, lying between the wood and the bark, and originally connected with both (Fig. 181, *e*, p. 77). They are formed in a mucilaginous fluid called Cambium, and they are concerned in the formation of the woody tubes of the inner bark, and of the pleurenchyma, as well as in the additions made to the cells of the medullary rays. When these cells are carrying on the process of growth with activity, during the flow of the sap in spring, the bark can be easily separated from the wood. We shall have occasion to allude to them afterwards, in speaking of the formation of wood.*

120. *The Bark* is at first composed of uniform cellular tissue, resembling that of the central part of the stem (Fig. 177, p. 73). In the progress of growth transformations of the tissue take place, by which fusiform prosenchymatous tubes are formed in the inner portion of the bark next to the woody circle. This portion is called the *Inner Bark* or *Liber* (Endophlœum). It consists of thickened pleurenchyma (Fig. 45, p. 23), with some laticiferous vessels (Fig. 70, p. 30). It is

with large numbers, this expression becomes $C = \frac{(6\,D^2+8\,D^2)\,d\,V}{n\,D^3}$. The estimator who prefers measuring the circumference of the tree after having determined the diameter, may use the following formulæ:—

Let P be the circumference of the tree, and p = the circumference of a circle, whose diameter = 1; these 2 formulæ then become $C = \frac{4\,p\,d\,(P - p\,d)\,V}{n\,P^2}$, and $C = \frac{4\,p\,d\,V}{n\,P}$.

* Mirbel sur le Cambium, Archives du Museum, tom. i. 303.

the fibrous part of the bark (Figs. 178, *l*, 180, *l*, 181, *f*), and is often called *Bast* tissue. The fibres of the liber are long and tenacious, and are employed for various useful purposes. Those of the Lime-tree, Hemp (Fig. 47, p. 23), Flax (Fig. 46, p. 23), Mallow, Hibiscus, Boehmeria, Nettle, and Daphne cannabina, are employed for different articles of manufacture. The fibres sometimes separate, so as to form meshes, as in the Lace-bark tree; at other times they form a continuous layer, as in Horse-chesnut and Negundo. The inner bark of Antiaris saccidora has tenacious fibres, which are used in India for cordage and matting. The tree is common in the jungles near Coorg, according to Dalzell, and the people manufacture curious sacks from it. A branch is cut corresponding to the length and breadth of the sack wanted. It is soaked a little, and then beaten with clubs until the liber separates from the wood. The liber, in the form of a sack, is then turned inside out until the wood is sawed off, with the exception of a small piece left to form the bottom of the sack. These sacks are in general use among the villagers for carrying rice. The inner bark of various trees has been used for writing upon, and hence the name liber.

121. On the outside of the liber lies the cellular portion of the bark, consisting of two layers, the *Cellular Envelope* (Fig. 181, *g*, p. 77), called also Mesophlœum, and the *Corky* or *Suberous Envelope* (Fig. 181, *h*, p. 77), called also Epiphlœum. The former is composed of loose thin-walled polyhedral cells, containing chlorophyll, and hence often denominated the green layer; the latter consists of flattened tabular parenchyma, giving the peculiar colour to the branches and young stems of trees and shrubs. The Epiphlœum is rarely green; it is generally some shade of ash-colour or brown. It is sometimes developed to a great extent (Fig. 184, *s*, p. 81), constituting the cellular substance called cork, procured from the Cork oak (Fig. 173, p. 72), and produced also by various species of Elm.* In some trees the Epiphlœum falls off at certain intervals. In the Cork oak it does so in eight or nine years, leaving a tabular layer of cells below. In the Birch the outer bark is the part which separates in layers, owing to the formation of a stratum of thin-sided cells below the lamellæ, which easily separate into fine powder when disturbed. On the outer surface of the Epiphlœum is the Epidermis, or general integument, which in old trunks is thrown off.

122. The different layers of bark increase by additions of new cells to their inner surface. The cellular layers, however, soon cease to

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* Cork, next to cellulose, is said by Mitscherlich, to be a most important constituent of the cell-wall. He states, that in the potato, the cells, consisting of cellulose, are filled with starch, and they are easily distinguished from the cork-cells by their chemical re-action. Concentrated sulphuric acid dissolves cellulose immediately, but does not act on cork until after the lapse of a considerable time. Nitric acid of sp. gr. 1·2, oxidises cork even below the boiling point of water; the cells first swell, and the product is then soluble in potash; they afterwards separate from each other, and by the continued action of nitric acid a series of acids is formed, the final members of which are suberic and succinic acids. See paragraph 52, p. 31.

grow, while the liber continues to increase by additions from the cambium layer. The thickening of the pleurenchyma of the liber takes place by concentric deposits of lignin, in the same way as in the case of woody tubes. Sometimes the different annual circles of bark may be traced, as shown in the young oak stem (Fig. 182, p. 78); but in general, after a certain length of time, all the layers are more or less amalgamated by the growth and pressure of the parts below, so that it is impossible to ascertain the age of the tree by the cortical layers. It is obvious that, by the constant additions to the wood on its outside, and the bark on its inside, the latter is distended, and when the cellular portion has ceased to grow, it cracks and splits in various ways, and ultimately falls off. The distention and increase in diameter of an Exogeneous stem is such, that a woody climbing plant, for example Bauhinia or Honeysuckle, when surrounding it, gives rise to marked grooves on the surface (Fig. 185), and often arrests its growth entirely by pressure on the sap wood.

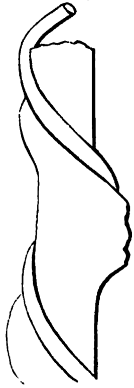
Fig. 185.

123. Recapitulation of the different parts of an Exogenous Stem :—

1. Pith, Medulla, in the centre, composed of cells, frequently hexagonal.
2. Medullary Sheath, consisting chiefly of Spiral Vessels.
3. Woody layers, composed of Pleurenchyma and Dotted Vessels, arranged in zones, which are formed successively one outside the other.
4. Medullary Rays, formed of muriform cellular tissue, connecting the pith and bark.
5. Cambium layer, composed of cells, often fusiform, separating the wood and bark, and concerned in the formation of new wood and bark.
6. Liber, Inner Bark, Endophlœum, woody in structure, made up of long pleurenchymatous tubes, and some laticiferous vessels, additions being made internally.
7. Outer Bark, consisting of—
    - *a.* Green Cellular Envelope, Mesophlœum.
    - *b.* Corky or Suberous Envelope, Epiphlœum. The additions to the outer bark are made internally, and the parts are often thrown off in the progress of growth.
8. Epidermis, or Condensed Cellular Integument, covering all the organs, frequently thrown off in the progress of growth, and replaced by other cellular formations.

124. Although all these parts are generally observed in Exogenous stems, and present the order now mentioned, still, various peculiarities occur, especially among exogenous trees of warm climates, which often obscure the arrangement. Thus, in some trees of great age only one marked zone or circle of woody matter is seen, consisting of a series of separate wedges; in other trees there are several such

Fig. 185. Stem of an Exogenous tree, surrounded by a woody climber, which has caused contractions at different parts. In the West Indies such climbers constitute the Bush rope, an excellent specimen of which has been deposited, by W. H. Campbell, Esq. of Demerary, in the Museum of the Edinburgh Botanic Garden.

zones, each of which is the produce of more than one year's growth. In such cases the stem increases in diameter by the formation of new wedges, or by additions to the old ones. Occasionally the woody matter is so formed as to be in separate masses, surrounded by cellular tissue, which presents the same appearance as the outer bark (Fig. 186). Such a stem looks as if it were formed by several united together.*

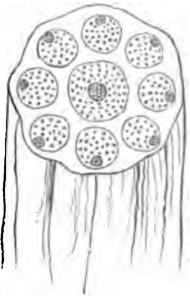
Fig. 186.

125. Many Exogenous plants with twining stems become much altered by compression. Other exogens exhibit fluted stems. In the Yarroura wood,† or Paddle-wood (Aspidosperma excelsum), large specimens of which have been presented by Dr. W. H. Campbell and Mr. Gourlie, to the Edinburgh Botanic Garden Museum, the stem is singularly fluted, and presents a waved or sinuous aspect. The same kind of appearance is seen in some woods which are imported for the purpose of furnishing dyes, such as Logwood, Nicaragua wood, and Rio de la Hache wood (Cæsalpinia echinata), &c.‡ In many anomalous stems the separable bark will lead the student to the determination of the Exogenous structure. In some of the lower class of plants a cellular stalk is produced, which on a transverse section presents an appearance like that of an Exogenous stem. Thus Lessonia fuscescens, a species of sea-weed, has stems which are often five to ten feet long, and as thick as the human thigh, and which show concentric elliptic cellular rings. Such is also the case with Usnea melaxantha, a tree-like lichen. In these plants, however, the structure is entirely cellular, and quite distinct from that of Exogenous plants.

126. *Branches of Exogens.*—In Exogenous stems a provision is usually made for the formation of branches, or, in other words, the stems grow, not merely by producing buds at the apex, which cause an increase in height, but also by lateral buds which give origin to branches (Figs. 172-5, pp. 72, 73). These are connected with the centre of the stem, and their tissues can be traced to the pith and its sheath.

Fig. 186. Peculiar fasciculated stem of a Malpighiaceous plant of South America. The plant is Dicotyledonous. The stem presents an example of an anomalous Exogen. It consists of numerous woody masses, having each distinct pith, and surrounded by cellular tissue, resembling that of the outer bark.

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* For an account of anomalous Exogenous stems, see De Jussieu, Monographie de la Famille des Malpighiaceæ, Archives du Museum, tom. iii., 5, 255; Mirbel, sur l'organisation de la tige d'un tres vieux Calycanthus floridus, Annales des Sciences Nat. 1st ser., tom. xiv. 367; Gaudichaud, Recherches generales sur l'organographie, la physiologie, et l'organogenie des Vegetaux, Paris 1841; also article Exogen in the Penny Cyclopædia. Some interesting specimens of anomalous Brazilian Exogenous stems, collected by the late Dr. Gardner, are now deposited in the Museum of the Edinburgh Botanic Garden.

† The wood is the Yarroura or Hussara of the Indians, according to Bentham. The trunk of the tree has a fluted appearance. The wood is elastic, and very strong. The fluted projections of the trunk are used for the construction of paddles. The wood was formerly used for the formation of what are termed gin-rollers in manufacture.

‡ Specimens have been deposited in the Edin. Bot. Museum by Michael Connal, Esq.

From this mode of growth Exogenous trees have a form more or less tapering as regards their stem and branches. In the arrangement of their parts, branches resemble the stems from which they proceed. When regularly developed they taper to a point, and continue to produce buds, which again form smaller branches and twigs by constant subdivision.

127. The mode in which branches grow and subdivide gives rise to different aspects in forest trees. In the Cedar (Fig. 175, p. 73), the branches spread nearly at right angles; in the Italian Poplar they come off at an acute angle with the upper part of the stem; in some plants, as the Weeping Elm, they come off at an obtuse angle. In the Birch and Willow the branches become so slender at their extremities that they bend by their own weight. When the terminal bud of a stem or branch of an Exogen is cut off or arrested in its growth, the lateral buds are produced abundantly, and thus give rise to the appearance seen in pollard trees, and in the clustering of the twigs of the Birch and other trees. The comparative length of the branches in the upper and lower parts of trees tends also to give them a peculiar physiognomy. When the lowermost are longest, and the others are gradually shorter as we proceed upwards, the conical form is produced, as seen in the Douglas Pine (Abies Douglasii). When the uppermost are longest, as in Pinus pinea, the form is somewhat like that of an inverted cone.* When branches are produced under ground, and in darkness, they frequently become thickened and contorted in various ways, as seen in the potato, the tuber of which is a branch of this kind. When the potato is allowed to grow above ground, but in darkness, the ordinary branches sometimes assume the form of tubers.

B. *Endogenous Stem, or the Stem of Monocotyledonous Plants.*

128. This kind of stem is not seen in its fullest development in northern climates. We must look to the palms and screw-pines of warm regions, in order to see the striking effect produced by its mode of growth. The trunks of palms differ much in their aspect from the trees of this country. They have usually simple unbranched, cylindrical stems, towering to a great height, and covered by a large mass of remarkable foliage. The general physiognomy of palms is seen in the form of the Date-Palm (Fig. 187), the Wax-Palm (Fig. 188), the Oil-Palm (Fig. 189), the West Indian Cabbage-Palm (Fig. 190), the Talipot Palm (Fig. 191), and the Coco-nut Palm (Fig. 166, p. 70).†

129. In the structure of the woody endogenous stem there is no marked distinction between pith, wood, and bark, there are no medullary rays, nor concentric circles. Definite vascular bundles are dif-

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* The forms presented by trees are well given in Selby's work on British Forest Trees; and their effect on the landscape is noticed by Mr. H. Twining, in his work on Picturesque Scenery, p. 83; as well as in Gilpin's Remarks on Forest Scenery.

† See Martius's large work on Palms, for delineations of their forms, and the character which they give to tropical scenery.

fused through the cellular tissue without apparent regularity, and the whole is enclosed by an external covering which differs from the bark of Exogens, in not having annual layers, and in not being separable from the wood. In Figure 192, which exhibits a transverse section of a Palm stem, this arrangement of tissues is seen. On the outside is the cortical portion not separable from the rest; the vascular bundles are marked *f*, and the cellular portion, which is looser towards the centre, *m*. In the early state the stem is entirely cellular, but in the progress of growth vascular bundles are produced, consisting of woody, spiral, dotted, and laticiferous vessels. In Figure 193, there is represented a transverse section of one of the fibro-vascular bundles of an Endogenous stem; upper *p* marking the general cellular parenchyma surrounding the bundle; lower *p*, woody fibres; *l l*, woody vessels analogous to those of the liber; *t*, tracheæ (spiral vessels); *v*, dotted vessels of large calibre; *v l*, laticiferous vessels. The vascular bundles are most abundant near the circumference, while the cellular tissue is in larger quantity in the centre (Fig. 192). In the bundles the woody vessels (Fig. 193, *l l*), generally surround the other vessels. A diagram of the stem of a monocotyledonous plant is given in Figure 194, A being a transverse, and B a longitudinal section. The cellular tissue which abounds in the centre, and which also exists between the

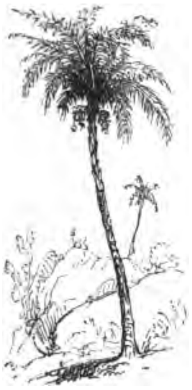


Fig. 187.

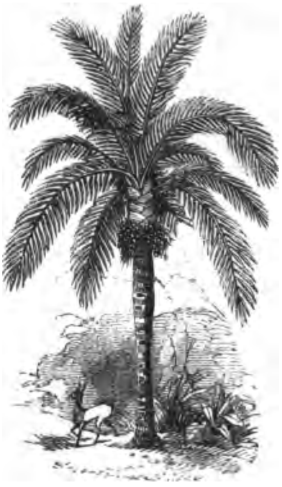


Fig. 188.

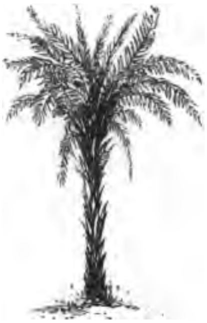


Fig. 189.

Fig. 187. Date Palm (*Phœnix dactylifera*). This is the Tamar of the Bible. (Exod. xv. 27; Psalm xcii. 12).

Fig. 188. Wax-Palm of South America (*Ceroxylon Andicola*). On the surface of its stem a waxy matter exudes, which is used by the natives.

Fig. 189. Oil-Palm (*Elais guineensis*). The palm which yields solid palm-oil, imported from Guinea in Africa. It also yields some of the best palm-wine. A specimen of the clustered fruit has been deposited in the Museum of the Edinburgh Botanic Garden, by Mr. Anderson of Liverpool.

vascular bundles, is marked *a a*. The vascular bundles are more abundant towards the circumference, consisting of dotted vessels, *b b;* woody fibres, *c c;* and spiral vessels, *d d;* besides laticiferous vessels.

130. The vascular bundles may be traced from the leaves downwards, some proceeding more or less directly towards the root, others curving outwards towards the cortical integument or rind (Fig. 195, *f v*). The mode in which these bundles proceed from the leaves towards the centre, in the first instance, has given rise to the term Endogenous, or inside-growers; the idea originally entertained by physiologists being, that the vascular bundles were always produced on the inside of those which preceded them. The bundles, however, although they have a tendency towards the centre at first, do not always remain there, but follow a curved course towards the periphery (Fig. 195), and in this way the outer rind becomes completely incorporated with them, so as not to be separable. The structure of the bundles varies in different parts of their course. Near the base of the leaves they contain all the vessels already mentioned, but as we trace them downwards, the spiral, dotted, and laticiferous vessels disappear, and the woody fibres alone remain when they reach the rind, or, as it is often termed, the false bark.

Fig. 191.

Fig. 190.

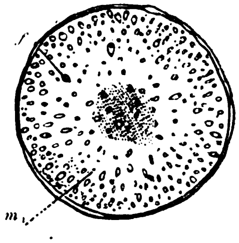


Fig. 192.

131. From the mode in which the vascular bundles are added, it will be seen, that the tendency is to push the older vessels outwards, and to render the periphery hard. In Palms, therefore, the hardest part of the stem is external, which is the reverse of what takes place

Fig. 190. West Indian Cabbage-Palm (*Areca oleracea*). The large terminal bud is used in the same way as cabbage.

Fig. 191. Talipot-Palm (*Corypha umbraculifera*). The fan-shaped leaves of this palm are of enormous size.

Fig. 192. Transverse section of the stem of a Palm, which is endogenous; *m*, the central loose cellular portion; *f*, the outer fibrous portion, shewing numerous vascular bundles. The whole being covered by a false bark or rind.

in Exogens. By the internal addition of vascular bundles from terminal buds only, and by the interstitial growth of cells, the stem of a Palm increases in diameter until it acquires the full limit to which the outer rind can be distended, and attains ultimately a uniform diameter throughout. Thus, there appears to be a definite limit to the lateral growth of a Palm, while no such limit can be seen in the case of Exogens, in which vascular bundles go on increasing indefinitely, and the bark is separable. Palms consequently do not exhibit trunks of a diameter equal to that of Exogenous trees, nor does their bole present a tapering form. The first part of the stem of a Palm is formed by vessels which are connected with the first crown of leaves; the next crown, or terminal bud, produces more woody bundles internal to the first, and thus the stem is thickened during successive seasons, until at length the lower part is fully formed. The same process goes on throughout the whole stem, until it acquires a continuous cylindrical form.

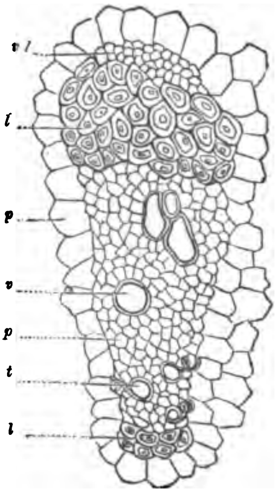


Fig. 193.

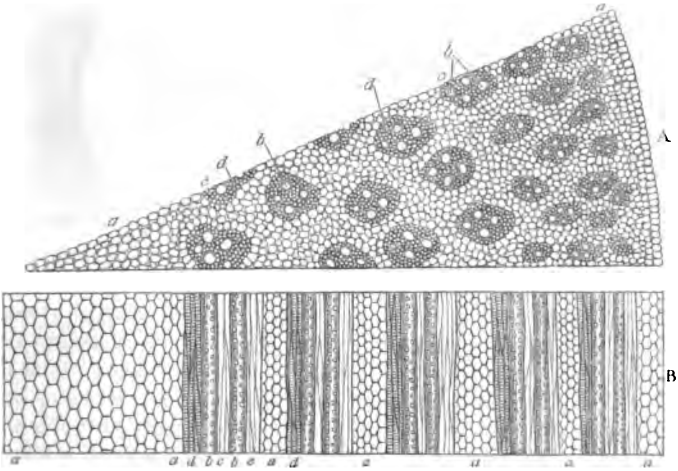


Fig. 194.

Fig. 193. One of the vascular bundles of a Palm-stem, the lower part of the figure being that next the centre. Upper *p*, the general cellular parenchyma surrounding the bundle; lower *p*, woody fibres; *l*, *l*, fibrous thickened woody vessels, resembling those of the liber of exogens; *t*, tracheæ (spiral vessels); *v*, large dotted vessels; *v l*, laticiferous vessels.

Fig. 194. Diagram of a monocotyledonous stem, after Carpenter. A, Transverse section; B, longitudinal section; *a*, *a*, cellular tissue (Parenchyma); *b*, *b*, dotted vessels (Bothrenchyma); *c*, *c*, woody fibres (Pleurenchyma); *d*, *d*, spiral vessels (Trachenchyma).

132. From the structure and mode of growth of a Palm-stem, it follows, that a woody twining plant does not produce the same injury as in the case of an Exogen. In Figure 196 is shewn a Palm-stem, surrounded by a twining woody Bauhinia, which does no injury to the form of the stem. The contrast between the effects of such twiners on Exogenous and Endogenous stem, is seen in Figures 197 and 198. The stem of the former showing swellings and contractions, while that of the latter is unaffected. In the Exogenous stem the soft wood is external, and the stem increases much in diameter, while in the Endogenous Palm the soft part of the stem is internal, and the diameter is limited.

133. Palms grow in a uniform manner as regards height in their native countries, and their age may in general be determined by the length of their stem. The destruction of the terminal bud of a Palm stops its growth, in consequence of there being no provision for lateral buds. In some instances, however, Palms have lateral buds. This is particularly seen in the Doum Palm of Egypt (Hyphæne thebaica), which gives off branches in a forked, or what is called a dichotomous manner (Fig. 199). There are also many endogenous stems which produce lateral buds. The Screw Pine (Pandanus), for instance, has a branching stem (Fig. 167, p. 70, and Fig. 200); so also Dracæna, Bamboo, and Asparagus. In the Dragon trees (Dracæna), a remarkable increase of stem takes place in consequence of the cortical integument remaining soft, and capable of unlimited distension. The vascular bundles, after reaching the circumference in these plants,

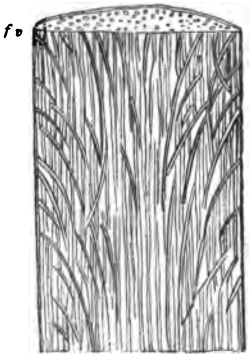
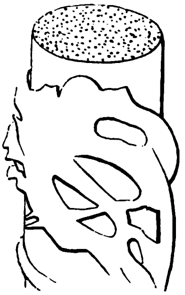


Fig. 195.



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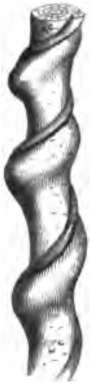

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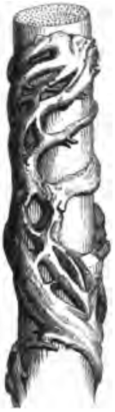

Fig. 198.

Fig. 195. Vertical section of a Palm-stem, shewing the vascular bundles, *f v*, curving downwards and interlacing. They proceed at first towards the centre of the stem, and then curve outwards.

Fig. 196. Stem of a Palm, surrounded by a woody twining Bauhinia. The palm-stem being uninjured.

Fig. 197. Exogenous stem, surrounded by a woody twining plant (Bush rope), which causes contractions and swellings of the stem.

Fig. 198. Endogenous stem, surrounded by a twining woody plant, and remaining uninjured.

descend towards the root, and being produced both by terminal and lateral buds, they are developed in large quantity, and thus give rise to enormous stems. Such a stem is seen in the famous Dragon tree of the Canaries (Fig. 201), which near the ground is 70 feet in circum-

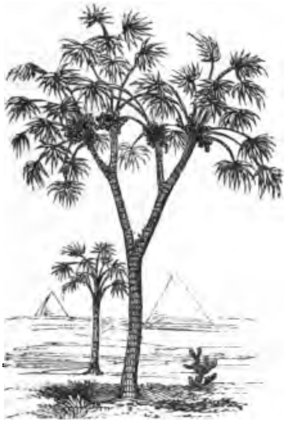
Fig. 199.

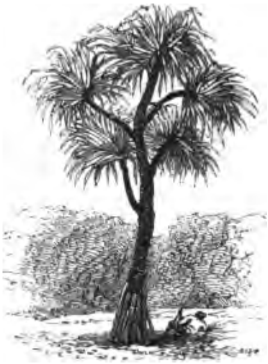
Fig. 200.

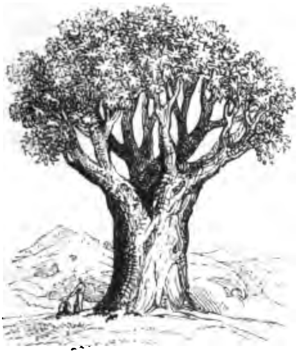
Fig. 201.

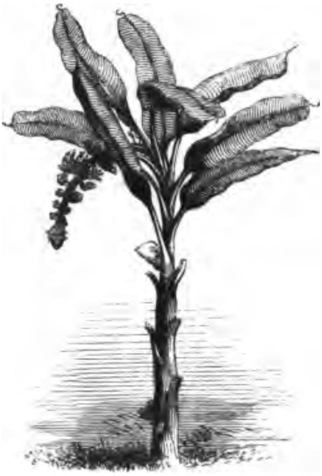
Fig. 202.

Fig. 199. Doum Palm of Egypt (*Hyphæne thebaica*), with its dichotomous stem. The stem is forked, and divides always by twos. It is one of the branching palms. Its fruit is used as food, and from the taste of the rind, it has been called gingerbread tree. It yields a resin called Egyptian Bdellium.

Fig. 200. Screw Pine (*Pandanus*), a branching Endogen, which sends off aërial adventitious roots abundantly from the lower part of its stem.

Fig. 201. Dragon-tree (*Dracæna Draco*) of Orotava, a branching Endogen, with a remarkably thick stem. See Humboldt's Vues des Cordilleres, &c.

Fig. 202. Banana (*Musa sapientum*), having an underground Endogenous stem, and sending up a herbaceous shoot, which bears leaves, flowers, and fruit.

ference. When numerous buds are produced laterally, the lower part of the stem receives more bundles than the upper, and thus the stem tapers. This is seen in the Asparagus and Bamboo, which in this respect resemble Exogens.

134. In some Endogenous stems the rapid growth of the outer part gives rise to a rupture of the central cells, and thus the hollow stems of many grasses are produced. In the Bamboo the hollow cavities in the stem are separated by partitions formed by the crossing of the vascular bundles. In Xanthorrhæa hastilis, the grass-tree of New Holland, a liliaceous plant, the structure of the stem and branches is peculiar. On making a vertical section the structure appears to be that of an Exogen. The woody part is formed of vertical loose fibres like Palms, and there are other fibres, radiating from the centre, and cutting the preceding at right angles. These horizontal fibres resemble the medullary rays, but differ in their structure. They probably serve for the origin of leaves, which are numerous, and are disposed throughout the whole length of the stem.*

135. Endogenous stems sometimes remain under ground. The corm (Figs. 159 and 161, p. 67, 68) is in part a shortened endogenous subterranean stem. Bulbs (Figs. 162 and 164, p. 68), are underground endogenous stems, covered with scales. In the Banana (Fig. 202), as well as in the Asparagus, the true stem is subterranean, and sends up shoots bearing leaves, flowers, and fruit, which, after dying down, are succeeded by other shoots. The peripherical portion of some subterranean endogenous stems, as Sarsaparilla, presents a circle of vascular wedges, resembling in appearance the stem of certain exogens; and the false bark of some aerial endogenous stems, as Testudinaria, becomes much thickened by the formation of cellular matter resembling cork.

C. *Acrogenous Stem, or the Stem of Acotyledonous Plants.*

136. This stem, in its complete development, is seen in the Tree-ferns of foreign countries (Fig. 165, p. 70). It resembles the Endogenous stem in being unbranched, and in producing a crown of leaves at its summit. The Tree-fern form gives a peculiar aspect to the vegetation of the countries in which it occurs. The structure of the stem, which is called a caudex, consists of cells and vessels, arranged in a peculiar manner. The vascular bundles are formed simultaneously. They consist of woody tissue, often of a dark colour, surrounding a paler layer of vessels, chiefly scalariform (Fig. 68, p. 29), and dotted. The bundles assume various shapes, giving rise to the zig-zag appearance, presented in a transverse section, as seen in Figure 203. The basis of these leaves (or fronds as they are called), by their union form the stem, which is increased by additions to the summit (Fig. 165,

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* A specimen of the stem of a Grass-tree (probably *Xanthorrhæa arborea*), has been presented to the Edinburgh Botanic Garden Museum by Dr. Neill.

p. 70); hence the name given of *Acrogens*, or summit-growers. The growing point is carried upwards by the leaves, and when once formed the stem increases very little in diameter. It is often hollow by the rupture of the internal cellular portion. On its outside the scars of the leaves remain (Fig. 204, *c*), with the markings of the vascular bundles. These bundles follow a course similar to that of the woody tissue of the liber of Exogens. The stem of Tree-ferns, then, is of moderate diameter, and does not produce lateral buds. Sometimes it terminates in two buds, which, by their growth, produce a forked stem. In the stems of the ordinary ferns of this country the acrogenous structure is seen, although they seldom attain any height, but usually creep along the ground, forming rhizomes. In Figure 205 is shewn a fern called Asplenium, with a creeping rhizome, giving off roots on its lower surface, and fronds (leaves) on the other, some of the fronds being rolled up in a circinate manner. The bases of the leaves are seen persistent, that is, remaining attached to the stem. Figure 204 exhibits the rhizome of the common Male Fern (Lastrea Filix-mas), with the scars, *c*, of the leaves.

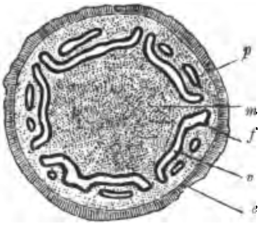

Fig. 203.

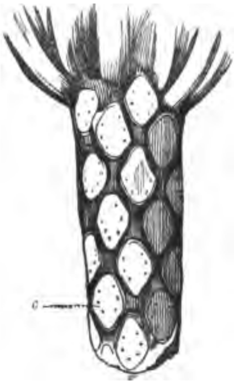

Fig. 204.

137. The acrogenous stem occurs in Horsetails (Fig. 34, p. 20), in Club-mosses, and in true Mosses, but in these plants it does not exhibit the same marked characters as in the permanent woody stems of Ferns. Many acotyledonous plants produce stems which consist entirely of cellular tissue without any admixture of woody fibre or vessels. Such stems are either aerial or subterranean. They appear as rounded stalks or flattened expansions rising into the air, or lying on the surface of the ground (Fig. 15, p. 12, and Fig. 50, p. 24).

Fig. 203. Transverse section of the stem of a Tree-fern (Cyathea); cellular tissue in the centre, *m*; that of the circumference, *p*; vascular bundles, *f v*, consisting of dark coloured woody fibres, *f*; and paler vessels, chiefly scalariform and dotted, *v*; the outer cortical portion formed by the basis of the leaves, *e*.

Fig. 204. Rhizome of Male Fern (Lastrea Filix-mas), shewing the scars (cicatrices) of the leaves (fronds), with the markings of the vascular bundles, *c*.

Sometimes they float in water like Seaweeds (Fig. 84, p. 37), at other times they creep under ground, or among the tissues of other plants, as in the case of Fungi. In Figure 11, p. 11, a representation is given of a Mould fungus, with root-like filaments at the base, constituting the spawn (mycelium) or creeping stem, which insinuates itself among the dead tissues of plants and other decaying substances. Occasionally, as noticed at paragraph 125, the cellular stems of seaweeds and lichens exhibit the appearance of concentric circles.

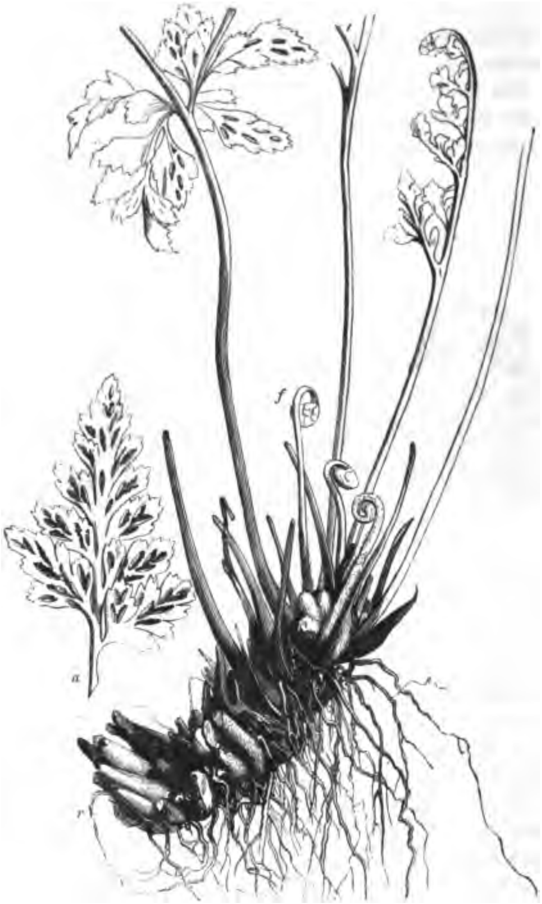

Fig. 205.

Fig. 205. Rhizome and fronds of Asplenium. The Rhizome, *r*, is covered with the bases of the leaves. Some of the fronds are in the bud, and are rolled up in a circinate manner, *f*. The fructification is seen on the back of the separated portion of the frond, *a*.

III. LEAVES AND THEIR MODIFICATIONS.

138. Leaves are important organs of nutrition, being the parts by means of which the sap of the plant is exposed to the agency of air and light. They proceed from the nodes (Fig. 146, *f*, p. 61) of the axis, and commence as cellular processes at the extremities of the medullary rays (Fig. 181, *i*, p. 77.) In the progress of development the cells multiply, vessels are produced which ramify in the form of veins, chlorophyll (¶ 59) is elaborated, and the foliar or leaf-organs, are thus completed. These organs usually spread horizontally, so as to expose one surface to the sky and the other to the earth—the surfaces differing in appearance and structure. When the position of their surfaces is reversed by artificial means, there is seen a marked tendency to recover their natural position. In some plants, as Alstroemerias, the leaf is twisted naturally upon itself, so that what should be the under surface becomes the upper. Erect or vertical leaves occur, in which both sides are equally exposed to light. In erect folded leaves, such as those of the Iris (Fig. 154, p. 65), the upper surface becomes lateral. In some New Holland plants the leaf-organs present their edges to the earth and sky.

1. ARRANGEMENT OF LEAVES ON THE AXIS.

139. The mode of arrangement of leaves on the stem has been denominated *Phyllotaxis*. It is regulated by certain definite laws, and depends on the development of the nodes and internodes of the stem and branches. When the internodes are so short that the stem is apparently awanting, the leaves are denominated *radical*, as in the Cowslip (Fig. 144, p. 60), and in the Dandelion. In such cases there is often at first sight some difficulty in determining the leaf-arrangement. When the internodes are elongated, and the nodes thus separated from each other, then the phyllotaxis is easily seen.

140. Each node is capable of producing a leaf or leaf-bud. When each of the nodes on an elongated axis produces a single leaf, the leaves are said to be *alternate* (Fig. 206), because they are placed alternately on different sides of the axis. When two leaves are produced at a node, they are called *opposite* (Fig. 207), because they are situated on opposite sides of the axis; while the production of three or more leaves at a node, gives origin to a circle or whorl of leaves, which are then said to be *verticillate* (Fig. 208).

141. *Alternate Leaves.*—This arrangement is a very common one, occurring generally in Monocotyledonous or Endogenous plants, and also being frequent among Dicotyledons or Exogens. The simplest arrangement is that in which the third leaf is placed directly above the first, while the second is placed on the opposite side of the stem,

separated by half the circumference of the circle. In this case there are two rows of leaves, one on each side of the stem, and the arrangement is said to be *distichous* (Fig. 209.) When the fourth leaf is above the first, on the same principle of the leaves being placed at equal distances on the axis, the arrangement will be *tristichous*, or in three rows, each leaf being separated from that next to it by one-third of the circumference of the circle. If the fifth leaf is placed above the first, the arrangement will be *tetrastichous*, or in four rows; if the sixth leaf, *pentastichous*, or in five rows. The last-mentioned arrangement is delineated in Figure 210, which represents the branch

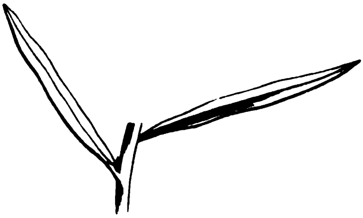

Fig. 206.

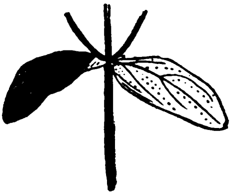

Fig. 207.

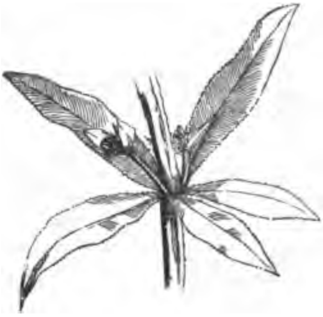

Fig. 208.

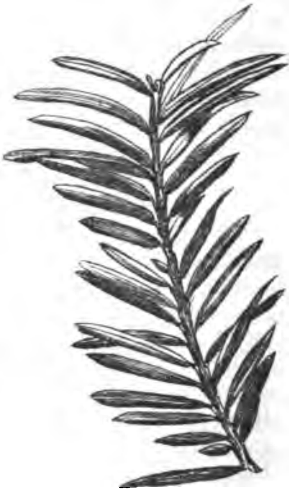

Fig. 209.

Fig. 206. Alternate leaves of Snap-dragon (*Linaria*). Each node gives off one leaf, or is unifoliar, and the leaves are placed alternately on the stem.

Fig. 207. Opposite leaves of St. John's wort *(Hypericum)*. The nodes produce two leaves, or are bifoliar.

Fig. 208. Verticillate or whorled leaves of one of the Madders *(Rubia)*. There are five leaves in the verticil or whorl.

Fig. 209. Distichous leaves of the Yew *(Taxus baccata)*. The leaves are in two rows, the third leaf being directly above the first.

of an oak with six alternate leaves, the sixth being placed vertically over the first.

142. It will be observed that, in following the course of the alternate leaves on the stem, we proceed in a spiral or screw-like manner, and that the termination of the spiral cycle is to be found in the leaf directly above that from which we commenced. On reaching it the cycle begins again, and goes through the same course as regards the number and arrangement of the leaves. Thus, in Figure 210, the cycle ends at the sixth leaf, which, in fact, commences the new spiral coil. In completing this spiral cycle we may make a single turn round the stem, as in distichous leaves (Fig. 209), or we may make two or more. Thus, in the pentastichous cycle we make two turns round the stem, and encounter five leaves besides the first (Figs. 210 and 211). The arrangement has, therefore, been marked by a fraction, of which the numerator indicates the number of turns round the stem, and the denominator the number of leaves in the cycle. This fraction, at the same time, gives the angular divergence of the leaves, or their distance from each other, expressed in parts of the circumference of the circle. Thus the fraction $\frac{1}{2}$ indicates distichous leaves (Fig. 209), where the angular divergence is one-half of the circumference of the circle, or 180°; the fraction $\frac{1}{3}$ implies tristichous leaves where the angular divergence is one-third of the circumference

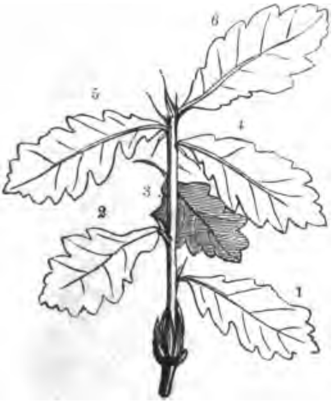

Fig. 210.

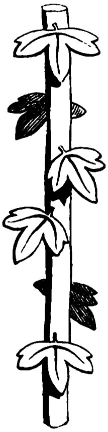

Fig. 211.

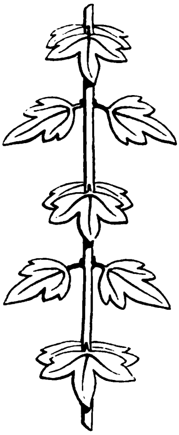

Fig. 212.

Fig. 210. Branch of oak *(Quercus pedunculata)*, shewing the pentastichous or Quincuncial arrangement of leaves. The leaves are placed alternately, so that the sixth is directly above the first, and commences the second cycle. The leaves are numbered 1, 2, 3, 4, 5, 6, according to their position.

Fig. 211. A stem with alternate leaves, arranged in a pentastichous or quincuncial manner. The sixth leaf is directly above the first, and commences the second cycle. The fraction expressing the divergence of the leaves is $\frac{2}{5}$. It is common among Dicotyledons.

Fig. 212. A stem with opposite leaves. The pairs are placed at right angles alternately, or in what is called a decussate manner. In the lowest pair one leaf is in front, and the other at the back; in the second pair the leaves are placed laterally, and so on.

of the circle, or 120°; the fraction $\frac{2}{5}$ applies to the pentastichous or Quincuncial arrangement (Fig. 211), a very common one among Exogens, in which the sixth leaf is immediately over the first, and two turns of the circumference are made before coming to it, the angular divergence being 144°.

143. The alternate phyllotaxis, and the angular divergence of leaves is explained more fully by Figures 213 and 214. In these it is shown that, in the case of alternate leaves, perpendicular lines may be drawn through the leaves placed directly over each other, and that the number of these lines indicates the number of leaves in each spiral cycle, or the number of leaves between any leaf on the stem and that directly above it. In both these Figures it will be seen that the number of these lines is seven, and this, consequently, is the number of leaves in each cycle. It is, therefore, a Heptastichous cycle, ending with the eighth leaf which commences the new spiral coil. But it will also be noticed that the number of turns made round the stem in completing the cycle is different. Thus, in Figure 213, commencing with leaf No. 1, we reach leaf No. 8, or that directly above 1, after making three turns round the stem, and the fraction indicating this is $\frac{3}{7}$; whereas, in Figure 214 we reach No. 8 after one turn, and the fraction, therefore, is $\frac{1}{7}$. These fractions mark the angular divergence between any two leaves of the cycle, as represented in the divided circles at the upper part of the stems. In Figure 213, between 1 and

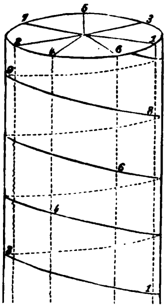

Fig. 213.

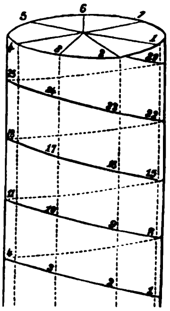

Fig. 214.

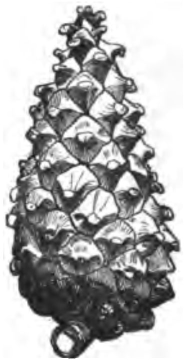

Fig. 215.

Figs. 213 and 214. Diagrams to illustrate the arrangement of the leaves on the stem. In each figure the spiral cycle consists of seven leaves. In Figure 213 the divergence between every two leaves is $\frac{3}{7}$. This will be seen by looking at the circle at the upper part, where the distance between 1 and 2 is obviously 3 of the seven divisions. In Figure 214 the divergence between every two leaves is $\frac{1}{7}$, as seen by the marks on the circle.

Fig. 215. Fir cone, consisting of numerous scales, which are metamorphosed leaves, arranged on a common axis, and covering the seeds. The scales are arranged in a spiral manner. One generating spiral passes through all the scales of the cone. There are numerous secondary spirals. The number of secondary spirals running parallel to each other indicates the difference between each scale in a single spiral. By this means all the scales may be numbered.

2 the angular divergence is obviously $\frac{3}{7}$ of a circle, or $\frac{3}{7}$ of 360° $= 154\frac{2}{7}°$, while, in Figure 214, the divergence is $\frac{1}{7}$ of the circle, or $\frac{1}{7}$ of 360° $= 51\frac{3}{7}°$.

144. The following are some of the usual modes of divergence of leaves, and their modifications :—

DIVERGENCE.	DICOTYLEDONS.	MONOCOTYLEDONS.	ACOTYLEDONS.
$\frac{1}{2}$ Distichous.	Asarum, Lime, Vicia, Orobus, Pea.	Common in Gramineæ, Cyperus, Acorus Calamus.	Fissidens, Didymodon capillaceus.
$\frac{1}{3}$ Tristichous.	Cereus triangularis (green fleshy divisions of the axis).	Carex, Colchicum autumnale.	Gymnostomum æstivum, Jungermannia trichophylla.
$\frac{2}{5}$ Quincunx.	Common in this class, Apple, Pear, Poplar, Cherry, Mezereon.	Eleocharis acicularis, Rhynchospora fusca.	Common.
$\frac{3}{8}$	Laurus nobilis, Holly, Aconite, Plantago.	Lilium candidum, Scirpus lacustris.	Common in mosses, Lycopodium Selago.
$\frac{5}{13}$	Wormwood, Euphorbia segetalis, Convolvulus tricolor, cones of White Pine, and White Spruce.	Agave americana, many species of Orchis.	Orthotrichum affine, Lastrea Filix-mas.
$\frac{8}{21}$	Isatis tinctoria, Plantago lanceolata, cones of Pinus Picea.	Gymnadenia conopsea, many species of Yucca.	Hypnum alopecurum, Polytrichum piliferum.
$\frac{13}{34}$	Euphorbia cæspitosa, Plantago media, cones of some Pines, Sempervivum arboreum.	Yucca aloefolia, Ornithogalum pyrenaicum.	Sphagnum, Polytrichum formosum.
$\frac{21}{55}$	Cones of some Pines. Mammillaria coronaria (protuberances on the axis).		

145. On looking at these fractions, and they embrace the common arrangements, it will be seen that they bear a constant relation to each other, for the numerator of each fraction is equal to the sum of the numerators of the two preceding fractions, while the denominator is the sum of the two preceding denominators; and the numerator of each is likewise the denominator of the next but one preceding.

146. In the case of stems with marked internodes, with few leaves in the cycle, and with the points of insertion small, these arrangements can be easily detected; but when the internodes are much shortened, and the leaves are very numerous, it is difficult to trace the arrangement. The general spiral arrangement, however, is well seen in cases where numerous leaves are approximated, as in the Screw-pine (Fig. 200, p. 91), and the number of vertical rows in such cases may

be easily detected. In the instance of the Fir cone (Fig. 215), which is composed of a series of scales, or metamorphosed leaves, covering the seeds, there is a very evident spiral arrangement, and a continuous series of spiral cycles will be found which pass through every scale of the cone. This generating spiral is not always readily detected, and it is difficult to determine the successive scales through which it passes. By examining the cone, however, there are seen numerous secondary spirals, proceeding some to the right, and others to the left. The scales in these stand to each other in regular arithmetical progression—the numbers indicating the differences between each scale being determined by the number of spiral cycles running parallel to each other. By this means all the scales may be numbered, and the generating spiral detected. A general tendency to alternation has thus been shown in the foliar arrangements of plants, and when they grow regularly the law of phyllotaxis can be ascertained correctly. The arrangement, however, is often much altered by interruption in growth, and other causes, so that we cannot in all cases detect its normal condition.

147. The Phyllotaxis is uniform in the same species, but it frequently varies in species of the same genus. Thus, in the European Larch, it is $\frac{8}{21}$, while, in the American Larch, it is $\frac{2}{5}$. The spirals proceed either to the right or to the left. The phyllotaxis of the branches is usually the same as that of the axis, and it is then called homodromous (a like course); but sometimes it is different, and called heterodromous (unlike course).

148. In typical arrangements, such as those noticed, there are always certain leaves placed directly over others in a straight series, the angle of divergence dividing the circumference into an exact number of equal parts. Such leaves are *rectiserial*, and are considered as being normal. Cases, however, occur, in which the angle of divergence is such, that it is not possible to divide the circumference by means of it an exact number of times, and hence no leaf can be exactly placed above another. Such cases are called by Bravais *curviserial*, being disposed in an infinite curve, and hence incapable of being placed in straight rows.*

149. *Opposite* and *verticillate leaves* are those in which two or more leaves are given off at a node (Figs. 207 and 208, p. 96). In them also there is seen a tendency to alternation and spiral arrangement as regards the pairs and whorls. Thus, in opposite leaves, the second pair is not directly above the first, but is placed either at right angles (Fig. 212, p. 97), and then called *decussate*, as in the mint tribe (Labiatæ), or slightly to one side, so that the third, or some higher pair of leaves, is that which is superimposed over the pair with which we commence, as in the Box (Fig. 216). So, also, in verticils, as in Galium and Madder (Fig. 217), the leaves of the second verticil are not directly over those of the first verticil, but are so situated as to be above the

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* Bravais, essai sur la disposition des Feuilles curvisériées. Ann des Sciences Nat. 2d ser. vii.

intervals between the leaves of the lower whorl. Verticillate leaves, as in Hippuris, sometimes become alternate, and then exhibit a distinct spiral arrangement.

150. The arrangement of the leaves furnishes characters in some families of plants. Thus, the Cinchona-bark tribe have opposite leaves; the Borage tribe, alternate; Labiate plants, opposite and decussate; the Madder tribe, verticillate or whorled. The arrangement of the leaves, however, is not always constant, and we occasionally meet with alternate and opposite leaves in the same plant. In some instances this anomaly may be traced to a non-development of the internodes,

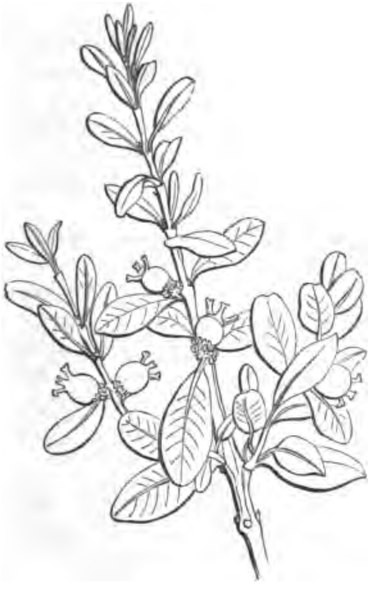


Fig. 216.

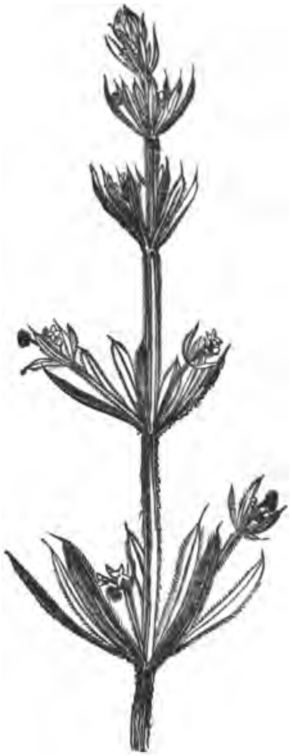


Fig. 217.

Fig. 216. Branch of the Box-tree (*Buxus sempervirens*), showing opposite leaves with the pairs alternating. It appears to be the Teashur of the Bible, mentioned in Is. xli. 19, and lx. 13. In Ezek. xxvii. 6, it is translated Ashurites, but the passage seems more properly rendered thus, "Of the oaks of Bashan have they made thine oars; and the benches of the rowers are made of Ashur-wood (box), inlaid with ivory."

Fig. 217. Verticillate or whorled leaves of Madder (*Rubia tinctoria*). The different verticils are arranged alternately with respect to each other.

by which two or more single-leaved (unifoliar) nodes are brought together. Thus, in Rhododendron ponticum, the alternate leaves, by such an arrestment, are sometimes seen almost verticillate. Again, in such plants as the Larch, Cedar, and Pine (Fig. 218), the arrestment of the internodes, according to a certain natural law in their development, gives rise to clustered or fascicled leaves. In the case of Pines, the clusters consist of two, three, four, or five leaves; while in the Larch and Cedar the leaves are indefinite. In the young elongating shoots of the Larch, the leaves assume an alternate arrangement.

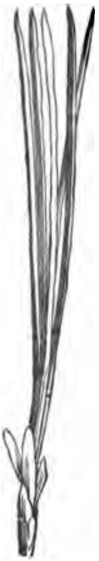


Fig. 218.

151. In the embryo state of dicotyledons, the leaves or cotyledons are opposite, (Fig. 113, *c c*, p. 49); while in monocotyledons, the production of one leaf at the node, shows the tendency to alternation (Fig. 114, *c*, p. 49). The early cotyledonary leaves are called *seminal* (Fig. 113, *c c*, p. 49); those afterwards produced, and constituting the ordinary leaves, are called *primordial* (Fig. 113, *g g*, p. 49). Leaves inserted on a shortened stem close to the ground, have been already noticed as *radical*, those on the main axis are *cauline*, on the branches, *ramal*, and on the flowering stalks, *floral* (Fig. 232, p. 105).

152. The form of the stem and branches appears to be in some degree regulated by the arrangement of the leaves. M. Cagnat thinks that the influence of Phyllotaxis is seen sometimes in both the wood and bark of the stem; sometimes in one of these parts only. He states that the form of the wood and bark do not always correspond. In European Rubiaceæ and Jasminum fruticans, the bark is angular, and yet the wood and pith are cylindrical. In Populus nigra the bark gives a round appearance to the stem and branches, while the wood and pith present distinct angles. In Nerium Oleander the young stem has three angles, and the leaves are in verticils of three, (Fig. 219); Labiatæ have opposite leaves and tetragonal stems; Hypericum tetrapterum has opposite leaves, and four wings on the stem. Again, as regards the form of the pith, which depends on the woody matter of the stem, Cagnat remarks that the leaves of Juniper are in verticils of three, and the pith is triangular; the leaves of Cypress are opposite, and the pith in the form of a cross. He thinks that, in the case of alternate leaves, the number of angles and wings is equal to the de-

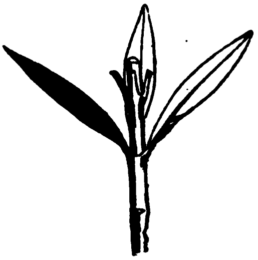


Fig. 219.

Fig. 218. Clustered or fascicled leaves of Weymouth Pine (*Pinus Strobus*). There are five leaves in the cluster, surrounded by scales at the base.

Fig. 219. Acute leaves of Rose-bay (*Nerium Oleander*), arranged in a verticil of three in the young state.

nominator of the cycle, or a multiple of it, or sometimes equal to the denominator minus the numerator.*

153. *Vernation*, or *Præfoliation.*—These names are applied to the arrangement of the leaves in the leaf-bud, and include both the mode in which each leaf is folded, and the relation which the leaves bear to each other. The leaf-bud is produced in the angle where a leaf joins the stem (Fig. 146, p. 61). It contains the growing point of the stem or branch, with its leaves and certain protective appendages called scales, tegmenta or perulæ (Fig. 145, *a*, p. 61). These scales or outer leaves are often of a coarse nature, covered with resinous matter, and arranged differently from the leaves in the interior, as may be seen in the common Sycamore.

154. The individual leaves in the bud are folded and rolled up in different ways. When the leaf is folded from its midrib, so that its halves are applied with their upper surfaces towards each other, as in the Oak and Magnolia, it is *conduplicate* (Fig. 220); when the apex is bent towards the base, as in the Tulip-tree, it is *reclinate*, or *inflexed;* when folded like a fan, as in the Maple and Vine, the leaf is *plaited*, or *plicate* (Fig. 224); when the leaf has each of its edges rolled inwards towards the midrib, as in the Violet and Water-Lily, the vernation is *involute* (Fig. 222); when outwards, as in Rosemary and Azalea, *revolute* (Fig. 221); when the leaf is rolled from one edge into a single coil, with the other edge exterior, as in the Apricot and Plantain, it is *convolute* (Fig. 223), when rolled from apex to base like a crosier, as in Ferns and Sundew, it is *circinate* (Fig. 225).

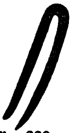
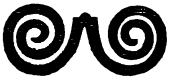


Fig. 220.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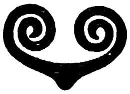
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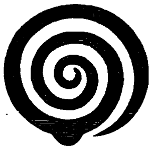
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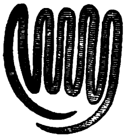
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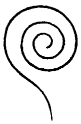
Fig. 225.

Fig. 220. Transverse section of a conduplicate leaf. The two sides of the leaf are folded on each other.

Fig. 221. Transverse section of a revolute leaf. The two edges are rolled outwards, away from the axis.

Fig. 222. Transverse section of an involute leaf. The two edges are rolled inwards towards the axis.

Fig. 223. Transverse section of a convolute leaf. It is rolled upon itself, so as to form a single continuous coil.

Fig. 224. Transverse section of a plicate or plaited leaf. Its parts are folded together like a fan.

Fig. 225. Circinate vernation, in which the leaf is rolled up from apex to base like a crosier.

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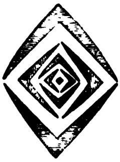
* Those who wish to examine the subject of Phyllotaxis more fully, may consult Steinheil, sur la Theorie de la Phyllotaxis. Ann. des Sciences Nat. 2d ser. Bot. iv. 100, 142; and xix. 321. Bravais sur la disposition des Feuilles. Ann. des Sciences Nat. 2d ser. Bot. vii. 42, 193; viii. 11, 161; xii. 5, 65. Cagnat sur la disposition des Feuilles. Ann. des Sciences Nat. 3d ser. Bot. ix. 362. Lestiboudois, Phyllotaxie Anatomique. Ann. des Sciences Nat. 3d ser. Bot. x. 15, 136. Henslow's Principles of Descriptive and Physiological Botany, page 123. Naumann, ueber den Quincunx als Grundgesetz der Blattstellung im Pflanzen-reiche, in Poggendorff's Annalen for 1842. Link, Elementa Botanica, ed. 2, ii. 448; Dutrochet, Mémoires, &c., i. 238. Schimper et Braun, Archives de Botanique, i.

155. The relative position of the leaves in the bud gives origin to the following terms:—*Valvate*, when leaves are placed in a circle, so as to touch each other at their edges only, without overlapping; *imbricate*, when the outer leaves successively overlap the inner to a greater or less extent (Fig. 226). These kinds of vernation occasionally become *twisted* or *contortive*. When involute leaves are applied in a circle without overlapping the vernation, is *induplicate;* when conduplicate leaves successively embrace each other, as at the base of the Iris, they are equitant (Fig. 227); and when the half of one conduplicate leaf covers half of another, the term *half-equitant* or *obvolute* is applied (Fig. 229); when a convolute leaf incloses another which is rolled up in a similar manner, the vernation is *supervolute* (Fig. 228).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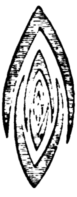
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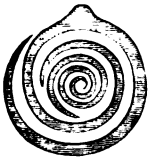
Fig. 228.

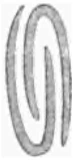
Fig. 229.

2. ANATOMY OR STRUCTURE OF LEAVES.

156. The Leaf consists of a cellular and vascular portion; the former constituting the Parenchyma—the latter, the Ribs and Veins. The whole is covered by an integument. The flat expanded portion is called the *Lamina*, blade or limb, (Fig. 230, *l*), consisting of cells traversed by vessels, and the narrow portion is called the *Petiole*, or leaf-stalk (Fig. 230, *p*), in which the cellular tissue is less abundant, and the vessels are more closely united. At the base of the petiole there are sometimes certain leafy appendages denominated *Stipules* (Fig. 231, *s*). The petiole is sometimes awanting, and the leaf is then *sessile* (Fig. 232); at other times the blade is transformed, so as to appear like a petiole, as in some aquatics such as Sagittaria. The leaf may be called generally a flattened expansion of the green layer of the bark, strengthened by woody fibres and vessels.

157. The Parenchyma varies much in its extent, and in the form of its cells. In fleshy leaves it is abundant, and its cells are loose, and more or less rounded. In an ordinary flat leaf there are two surfaces, one of which (the upper) is exposed to the light. The epidermis covering these surfaces consists of compressed colourless cells. That of the lower surface is often of a paler colour, and is provided with stomata (Figs. 92 and 93, p. 42) and hairs; while on the upper

Fig. 226. Transverse section of a bud, in which the leaves are arranged in an imbricate manner.

Fig. 227. Transverse section of a bud, in which the leaves are arranged in an equitant manner, overlapping each other at the edges.

Fig. 228. Transverse section of a bud, shewing two leaves arranged in a supervolute manner. Both the leaves are convolute, and one is rolled up within the other.

Fig. 229. Transverse section of a bud, shewing two leaves folded in an obvolute manner. Each is conduplicate, and one embraces the edge of the other.

side the epidermis is more tough and dense, and is either entirely destitute of stomata, or possesses them in small number. In leaves placed vertically, the stomata sometimes exist in equal number on both sides; in floating plants, as water-lilies, the stomata exist only on the upper surface of the leaf; while in submerged leaves no stomata occur on either surface, and the true epidermal layer of cells is absent (¶ 69).

158. The *Parenchyma* of ordinary leaves consists of two distinct layers of cells, one connected with the upper surface (looking to the sky), and consisting of compact oblong cells placed endwise (Fig. 233, *ps*); the other, connected with the lower side, consisting of loosely-aggregated cells, having numerous cavities between them (Fig 233, *pi*), and, when of an elongated form, placed with their long diameter parallel to the epidermis. The cavernous nature of the lower epider-

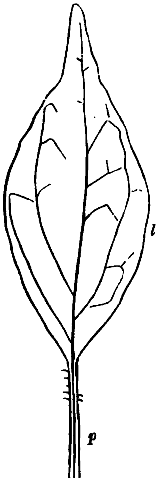

Fig. 230.

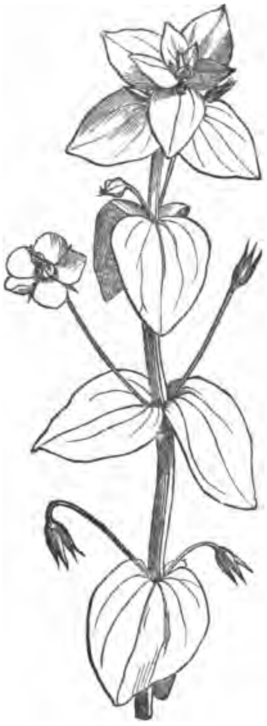

Fig. 232.

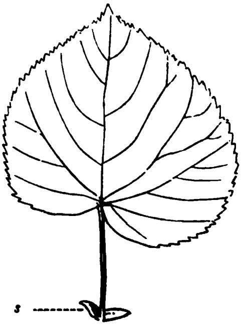

Fig. 231.

Fig. 230. Leaf of Pellitory (*Parietaria officinalis*), shewing the petiole or leafstalk, *p*, and the lamina or blade, *l*. The leaf is petiolate and acuminated or drawn out at the apex, and the venation is reticulated. The margin or circumscription is entire (integer).

Fig. 231. Oblique, petiolated and serrated leaf of Lime (*Tilia*), with stipules, *s*, at the base of the petiole. The leaf is obliquely-cordate at the base.

Fig. 232. Flowering stalk of Scarlet Pimpernel (*Anagallis arvensis*), shewing sessile or non-petiolated leaves, which are opposite to each other, the pairs being alternate and decussate. Single-flowered peduncles arise from the axils of the leaves, which are hence called floral.

mis seems to be connected in some degree with the stomata and their functions. The cells on the upper side are usually placed close to each other, without any space between them, except in cases where stomata occur (Fig. 233, *st*). In Figure 233 is given a section of a melon leaf perpendicular to the surface. The upper integumentary system is marked *es*; it shows hairs, *p*, on its surface, and two openings of stomata, *st*. Below the upper epidermis are layers of oblong cells, *ps*, with two spaces between them, *m*, communicating with stomata. The lower integument, *ei*, also exhibits hairs and stomata; and above it are layers of loose cells, *pi*, with numerous lacunæ, *l*. The vascular bundles running through the parenchyma are marked *fv*.*

159. Sometimes there are several layers of epidermal cells, more particularly in plants exposed to the heat of the tropical sun, as the Oleander (Fig. 234). When the lower surface of leaves is exposed to the sun, their moisture is rapidly evaporated, and they soon fade. The parenchyma is occasionally deficient at some parts of leaves, giving rise to deep indentations or to perforations. In Dracontium there are distinct holes in the leaves; and, in an aquatic plant of

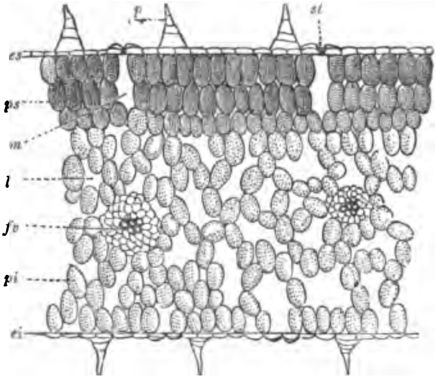

Fig. 233.

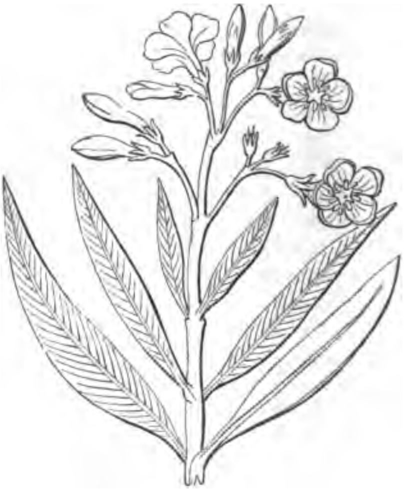

Fig. 234.

Fig. 233. Section of Melon-leaf, perpendicular to the surface; *es*, upper epidermis; *ei*, lower epidermis; *p*, hairs; *st*, stomata; *ps*, upper layers of parenchymatous cells; *pi*, lower layers of parenchymatous cells; *m*, meatus, or canals connected with stomata; they are sometimes called hypostomatic spaces; *l*, lacunæ, or cavities between the loose cells in the cavernous lower parenchyma; *fv*, bundles of fibro-vascular tissue, consisting of woody, dotted, spiral, and other vessels.

Fig. 234. Nerium Oleander, Rose-bay, Laurier-rose of the French, with long narrow lanceolate leaves, the upper epidermis of which is very dense. In the leaves are cavities with hairs, supposed to be a substitute for stomata. It would appear to be the *Rhodon* of the Apocrypha, translated Rose in Ecclesiasticus xxiv. 14, and xxxix. 13.

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* A full account of the anatomy of the leaf is given by Adolphe Brongniart, in Annales des Sciences Nat. 1st series, xxi. 420.

South Africa (Ouvirandra fenestralis), the tissue of the leaf is made up of interlacing filamentous cells, with perforations between them, giving the appearance of a skeleton leaf. In Victoria regia (Fig. 235) there are peculiar perforations in the leaves. These are formed by depressions of two corresponding points of the upper and under surface of the leaf, and are at first closed by a transverse membrane; after a short time the membrane disappears, and a clear passage is formed through the leaf. Some suppose that this contrivance is with the view of allowing the air to escape upwards, which would otherwise collect below the under surface of the leaf, in the spaces included by its deep ribs, and which would have a tendency to prevent the leaf from coming into contact with the water. In the plant called Hermas, the two layers of the leaf may be separated by a little effort, the hand being introduced between them. The surface of leaves is sometimes smooth (glabrous), at other times hairy (hirsute),

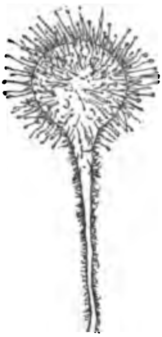
Fig. 236.

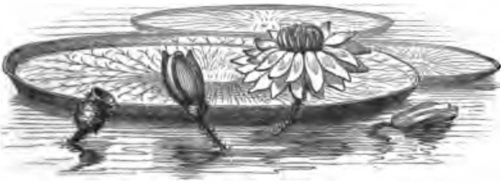
Fig 235.

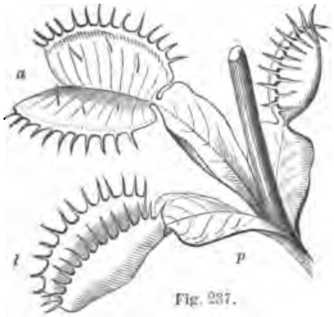

Fig. 237.

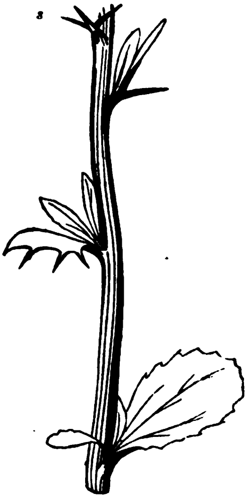

Fig. 238.

Fig. 235. Victoria regia, the largest known Water-lily, found in lagoons in South America. Its leaves are from 4-6½ feet in diameter, and its flowers one foot across. Besides stomata, there are peculiar perforations through the leaves to allow air to pass from the under to the upper surface. The plant has recently flowered in warm tanks in several hot-houses in Britain, as at Chatsworth, Sion House, Kew, Regent's Park, Veitch's Nursery Exeter, Knight and Perry's Nursery Chelsea; and in a heated pond in the open air at the Nursery of Messrs. Weeks and Co. Chelsea.

Fig. 236. Leaf of Sundew (*Drosera rotundifolia*), covered with glandular hairs. On account of the fringe of hairs round the margin, the leaf is called ciliated.

Fig. 237. Leaves of Venus's Fly-trap (*Dionæa muscipula*). The expanded blade of the leaf, *a*, exhibits three hairs on the surface of each half. These hairs when touched cause the folding of the blade, as shewn in the figure. The winged petiole, *p*, supports a half-closed lamina, *l*.

Fig. 238. Branch and leaves of the Barberry (*Berberis vulgaris*). The leaves are spiny. Some of them, as at *s*, are composed of hardened vascular tissue only.

downy (pubescent), or woolly. The hairs are either lymphatic or glandular. In the case of the Sundews (Drosera) the leaves are fringed with glandular hairs (ciliated), and their surface is covered with them (Fig. 236); while in Venus's Fly-Trap (Dionæa muscipula) there are irritable hairs on the leaves, which, when touched, cause the two sides of the leaf to fold together (Fig. 237).

160. The *Vascular system* of the leaf (Fig. 233, *fv*) is composed of a double layer of vessels which may be separated by maceration. It consists of woody, laticiferous, dotted, and various kinds of spiral vessels. These vessels collectively form the petiole or stalk, and spread out in the lamina or blade, so as to constitute the veins. When a leaf is macerated, the cellular tissue is separated, and the vascular bundles alone remain. In some leaves, as in the Barberry, the vessels forming the veins are hardened, producing spines without any parenchyma (Fig. 238, *s*). The hardening of the extremities of the vascular tissue is the cause of the spiny margin of many leaves, such as the Holly (Fig. 239), of the sharp-pointed leaves of Madder (Fig. 217, p. 101), and of mucronate leaves, or those having a blunt end with a hard projection in the centre.

161. De Mercklin* states, that leaves have their origin in cellular papillæ arising from the axis. Their apex is the first part formed, and it is pushed forward by the growth of the part below. The leaf-stalk is formed after the blade, the lower part of it being the last developed. Leaves are undivided in their early state, all the divisions which take place in them are subsequent formations. The mode in which the parenchyma increases, and the arrangement of the veins, give to the leaves their varied forms.

162. *Venation.*—This term has reference to the arrangement of the vascular tissue of the leaf. This tissue consists of firm and prominent bundles of vessels called *ribs*, and others less conspicuous, denominated *veins*. The term nerve, as applied to the vessels of the leaf, is now generally given up to avoid ambiguity as to function. In Figure 240 there is given a representation of a vertical section of a branch, shewing the mode in which the vascular bundle, *fv*, gives off a prolongation to the leaf-stalk, *f;* the vessels passing from the sheath surrounding the pith, *m*, through the parenchyma, *pc pc*, and communicating with the young bud, *b*, in the axil of the leaf.

163. There are two marked forms of venation, one in which the vessels from the petiole or stem, on entering the leaf, are continued in the form of one or more ribs, which give off branches on either side, and form an anastomosis or net-work of vessels (Figs. 241, 242); the other, in which the vessels, when entering the leaf, divide into several veins or ribs, which run more or less parallel to each other, and are united by simple transverse veins, as in Palms (Fig. 243), the leek (Fig. 244), and grasses; or in which the midrib gives off lateral veins

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* De Mercklin, observations sur l'histoire du développement des Feuilles, Annales des Sciences Nat. Bot. 3d ser. vi. 215.

which run parallel, as in the Banana (Fig. 245). The former are *Reticulated* or *Netted* leaves, and are common in dicotyledons, while the latter are *Parallel-veined*, and are characteristic of monocotyledons.

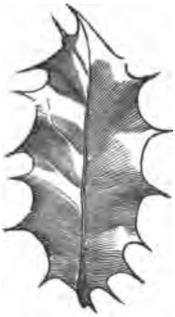

Fig. 239.

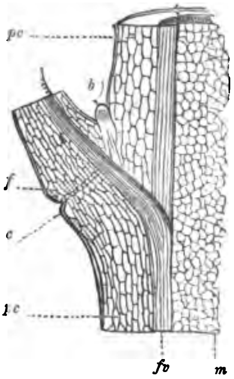

Fig. 240.

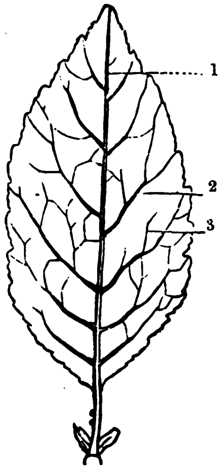

Fig. 241.

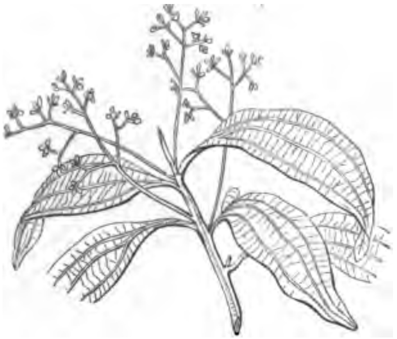

Fig. 242.

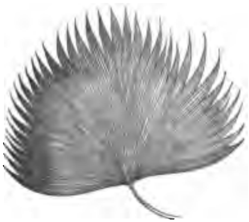

Fig. 243.

Fig. 239. Spiny leaf of Holly (*Ilex Aquifolium*). The spines are formed by the hardened extremities of the veins proceeding from the midrib to the margin.

Fig. 240. Vertical section of a branch, shewing the mode in which the vascular tissue of the leaf communicates with the centre of the stem; *m*, pith; *fv*, fibro-vascular tissue around the pith, giving off a branch to the leaf, *f*, which is articulated to the axis; *pc*, *pc*, parenchyma of the stem; *c*, cushion or cellular swelling below the leaf; *b*, bud in the axil of the leaf.

Fig. 241. Petiolate and stipulate leaf of Cherry, shewing the reticulated venation with a single midrib (unicostate). The midrib, 1, is a continuation of the petiole, and it gives off primary veins, 2, which again sub-divide into secondary veins, 3, curving within the margin.

Fig. 242. Three-ribbed (tricostate) leaves of Cinnamon (*Cinnamomum zeylanicum*). In these leaves there is one central rib and two lateral ones. The venation is reticulated. The plant is the Kinnamon and Kinnamomum of the Bible, noticed in Exod. xxx. 23; Prov. vii. 17; Cant. iv. 14; and Rev. xviii. 13.

Fig. 243. Leaf of Fan-Palm (*Chamærops*), shewing the veins running from the base to the margin, and not forming an angular net-work.

164. In reticulated leaves there is either one primary rib called *midrib* (Fig. 241, 1), or there are several prominent ribs, as in Cinnamon (Fig. 242), and Cassia (Fig. 246). When a single midrib is present it gives off branches or veins, which either proceed directly to the margin, as in the *feather-veined* leaves of the Oak (Fig. 210, p. 97), Chestnut, and Holly (Fig. 248), or which end within the margin in curved veins as in Lilac, Cherry (Fig. 241), and Dead-nettle (Fig. 247); in the latter case, marginal veinlets proceed from the curved veins. When there are three prominent ribs, as in Cinnamon (Fig. 242), and Cassia (Fig. 246), the leaf is *tricostate;* when five, *quinquecostate.* When the midrib gives off two ribs a little above the base, the leaf becomes *triplicostate;* when it gives off five, *quintuplicostate.*

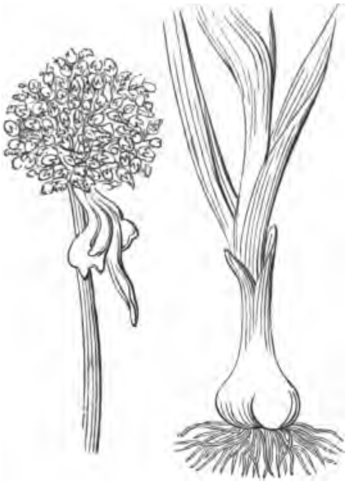

Fig. 244.

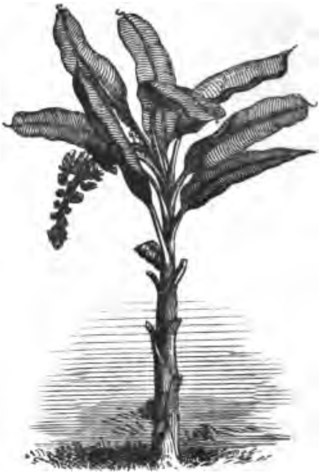

Fig. 245.

165. In a leaf having many ribs, they may converge towards the apex, as in Cinnamon (Fig. 242), or they may diverge. In the latter case, they are said to radiate, and they give origin to *palmate* and *palmatifid* leaves, as in Sycamore, Mallow, and Castor oil (Fig. 249). Parallel-veined leaves have either a single midrib, the veins from which come off in a parallel manner, and run to the margin without forming a net-work, as in the Banana (Fig. 245), and Indian Shot (Canna);

Fig. 244. Leek *(Allium Porrum)*, with parallel-veined sheathing leaves, proceeding from a bulb or underground bud. The flower-stalk is separated, showing the umbellate cluster of flowers, and below it the bract or floral leaf. The plant seems to be the ***Chatzir*** of the Bible, which is translated Leeks in Numb. xi. 5; but in other places is translated grass, herb, hay, &c. It is the ***Prason*** of the Greeks.

Fig. 245. Banana (***Musa sapientum***), shewing parallel-veined leaves, with sheathing petioles, which form the temporary stem. There is a single midrib in the leaf, from which parallel veins proceed to the margin. The leaf splits easily in the direction of these veins. There is no angular net-work of vessels.

or they have numerous veins or ribs running from base to apex, converging as in Grasses (Fig. 250), and Lilies; or diverging, as in Palms (Fig. 243).

166. In very succulent plants, as the American Aloe (Agave americana), and Fig-Marygolds, where the parenchyma abounds, the veins are obscure, and in plants such as Mosses and Sea-weeds, the so-called veins are composed of an aggregation of long cells, without any woody fibre. In many plants belonging to the Myrtle order (Myrtaceæ), which have ribbed leaves, there is an obscure vein which runs from the base to the apex of the leaf, close to the margin, and in which the lateral veinlets end. The primary veins come off from the midribs of leaves at different angles, and thus contribute to give form to the leaf. Primary veins coming off at a very acute angle, and converging, give rise to narrow leaves; those proceeding more at a right angle frequently produce broad leaves; while those coming off at obtuse angles cause prolongations at the base of the leaf. So also with veins radiating from a point, their greater or less divergence gives origin to leaves of a broader or a narrower form.

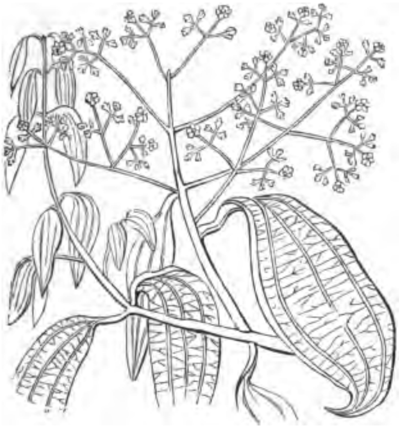

Fig. 246.

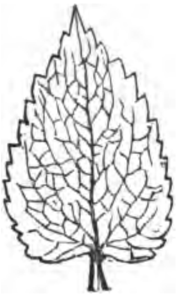

Fig. 247.

167. Lestiboudois remarks that the arrangement and form of the foliaceous appendages of plants depend much on the number, the development, and the relation of the fibro-vascular bundles of the stem. In vascular plants the skeleton of the leaf is formed by an expansion of the fibro-vascular bundles of the stem. The leaves contain vessels similar to those forming the bundles at the point where they escape from the axis. The vascular bundles, as well as the parenchyma of

Fig. 246. Cassia-bark tree *(Cinnamomum Cassia)*, shewing ribbed leaves. There are three marked ribs, and the leaf is hence called tricostate. Venation is reticulated.

Fig. 247. Leaf of Dead-nettle *(Lamium)*, shewing reticulated venation, the primary veins ending within the margin in curved veins. The edge of the leaf is serrated (saw-like).

the stem, expand in the leaf in various ways. In the cicatrices of fallen leaves (Fig. 145, *b*, p. 61), the number and arrangement of the ruptured bundles are seen. In each plant the leaves receive a special number of vascular bundles; sometimes a single bundle, as in Dianthus, sometimes several, as in Clematis, Horse-chestnut, and Elder, sometimes all the bundles which surround the axis of the stem, as in a great number of Monocotyledons. These bundles constitute the ribs of the leaves; amongst these ribs there is usually one which is median, and it marks the true position of the foliaceous expansion, determining the real point of emergence. It is distinguished from the others by bearing a bud in its axil. The caulinary bundles, after their exit from the stem, ramify, at other times they remain undivided for a longer or shorter space. Hence the differences of petiolate, sessile, and sheathing leaves. The bundles which constitute the

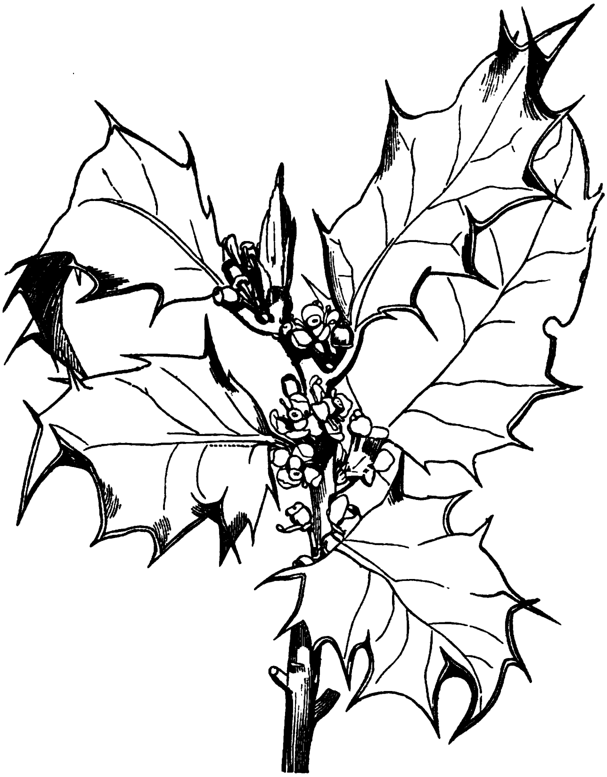

Fig. 248.

Fig. 248. Holly *(Ilex Aquifolium)*, shewing spiny single-ribbed (unicostate) leaves, with the primary veins going directly to the margin, their extremities being hardened and pointed. The leaf is said to be feather-veined.

frame-work (venation) of the leaves issue from the stem at different points. The disposition of the leaves on the stem, and their relation to each other, therefore, vary. The latter depends on the number and the symmetry of the caulinary bundles, and their mode of evolution.*

168. Dr. M'Cosh† thinks that the venation of leaves bears an analogy to the distribution of the branches, so that the leaf and its veins represent the stem and branches of the plant. He considers that in plants there are three homotypal parts, morphologically allied, and representatives of each other, viz. the root and its ramifications, the stem and its branches, and the leaf with its veins. These parts he looks upon as typically analogous. He has carried out his researches chiefly in regard to reticulated leaves. The angles at which the veins

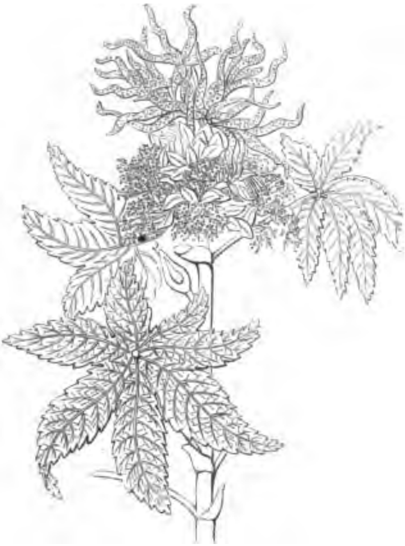

Fig. 249.

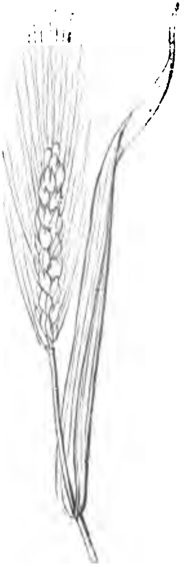

Fig. 250.

Fig. 249. Castor-oil plant *(Ricinus communis)*, shewing palmately-cut leaves, with radiating and reticulated venation. It seems to be the Hebrew *Kikayon*, translated Gourd, in Jonah iv. 6, 7, 8, 10, &c. It has been called Pentadactylus and Palma Christi, from the palmate division of its leaves. The Greeks called the plant *Kiki*.

Fig. 250. Spelt, a kind of wheat *(Triticum Spelta)*, shewing a parallel-veined leaf. The veins run along the whole length of the leaf, slightly convergent towards the apex. There are no reticulations. This kind of wheat is by some supposed to be the Hebrew *Kussemeth*, translated Rye, in Exod. ix. 32, and Isa. xxviii. 25; and Fitches, in Ezek. iv. 9.

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* Lestiboudois, Phyllotaxie Anatomique, ou Recherches sur les causes organiques des diverses distributions de Feuilles, Annales des Sciences Nat. Botan. 3d ser. x. 15, 136.

† M'Cosh on the plant morphologically considered, in the Proceedings of the Edin. Botanical Society for July 1851, Botanical Gazette, Sept. 1851, p. 118. Also, in the Transactions of the Edin. Bot. Soc. vol. iv.

are given off, he considers as being the same as those at which the branches come off, and he has attempted to prove this position by numerous measurements of angles. In trees there is a certain normal angle at which branches are given off, producing a peculiar physiognomic effect. This angle may be much modified by circumstances, and it may vary according to the age of the branches. The determination of this angle is a point to which M'Cosh calls attention, and his researches lead him to adopt the view that the same angle will be found to prevail in the leaf-formation.

169. The following table gives the results of numerous measurements, by M'Cosh, of the angles of branching and venation, where these were found to agree—the angles being those formed below the points where the veins and branches arise :—

	Deg.
Alder	50
Ash	60
Bay Laurel	50-60
Beech	45
Birch	48-35
Bird Cherry	60
Box	60
China Aster	28-30
Cherry	50
Clarkia elegans	36-40
Elm	50
Fuchsia	60
Hazel	42-43
Holly	55
Horse-chestnut	50-55
Jessamine	40-45
Laburnum (small branches)	60
Lilac	58
Lime	40
Mountain-Ash	45
Oak (large branches)	50
(small branches and veins)	65-70
Portugal Laurel	50-60
Privet	50
Raspberry	42
Red Dog-Wood	45
Rhododendron	60
Rose	50
Service tree	48
Solidago Virgaurea	30
Spiræa Ulmaria	30-35
Sycamore	45
Thistle	60-70
Thorn (lowest branches)	35-50

In some leaves the small veins come off at a wider angle than the large veins; and in many trees, as in the Oak, the small branches come off at a wider angle than the large branches.

170. Dr. M'Cosh is disposed to think that the mode in which the vascular bundles come off from the axis has a counterpart in the branching of the stem. In some leaves the vascular bundles, on leaving the axis, are united together, so as to form a petiole, and afterwards diverge, while in others there is no stalk, and the vascular bundles at once spread out as veins on leaving the axis. In woody plants, he thinks, that a similar variety takes place in the branching. Thus, in the Privet, Box, Bay and Portugal Laurel, the leaves have little or no petiole, and the branches proceed from near the base of the stem or main axis; in the Cherry, Sycamore, Horse-chestnut, and Laburnum, the leaves have a pretty long petiole, and these plants have a considerable extent of unbranched axis or trunk.

171. The mode also in which the primary ribs are distributed in

costate leaves, has, according to Dr. M'Cosh, a counterpart in the branching. Thus, Sycamore, Currant, Vine, Geranium, and Mallow, have several ribs proceeding from the base of the leaves, and their branches tend to whorl round the axis. The Laburnum and Broom have three leaflets coming off from one point of the petiole, and their branches are also in threes. In some recent observations, Dr. M'Cosh also thinks that he has ascertained that the curve of the veins and that of the branches corresponds.

3. CONFORMATION OF LEAVES.

172. With few exceptions, every plant has leaves at some period of its growth. Even those which produce leafless stems have generally seed-leaves (Cotyledons) in their embryo state (¶ 74). The Dodders (Fig. 128, p. 54), and a few other plants, are exceptions to this rule. Leaves present various forms from the scales of Broom-rapes (Fig. 126, p. 54), and the linear leaves of Asparagus and Pines (Fig. 218, p. 102) up to the large foliar expansions of the Banana (Fig. 245, p. 110), and of the Talipot Palm (Fig. 191, p. 88). To the nature of the venation and the development of parenchyma all the leafy forms must be traced. Leaves are usually arranged under the heads of *Simple* and *Compound;* the former having a blade composed of one piece, and having no articulation beyond the point where they join the stem, as in the Oleander (Fig. 234, p. 106), and Castor-oil plant (Fig. 249); the

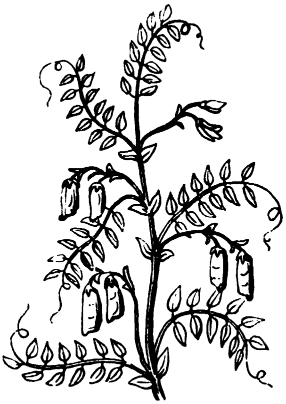


Fig. 251.

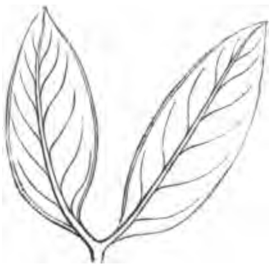


Fig. 252.

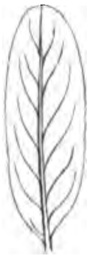


Fig. 253.

Fig. 251. Lentil *(Ervum Lens)*, having compound pinnate leaves ending in tendrils (cirrhi). Each leaf is composed of several (often six) pairs of leaflets (foliola, pinnæ), which are stalked and articulated to the midrib or common petiole, which terminates in a spiral tendril. The leaves are cirrhose. It is the Hebrew *Adashim*, and the Greek *Phacos*. It is mentioned in Gen. xxv. 34; 2 Sam. xvii. 28, xxiii. 11; Ezek. iv. 9.

Fig. 252. Ovato-lanceolate leaves of a species of Senna, probably a variety of *Cassia lanceolata*. The leaves are unequal or oblique at the base. The apex is acute.

Fig. 253. Oblong leaf of a species of Senna. The apex is obtuse or blunt, and the base is unequal.

latter having a blade divided into separate pieces or leaflets, which are articulated with the petiole (Fig. 251).

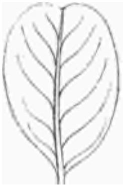


Fig. 254.

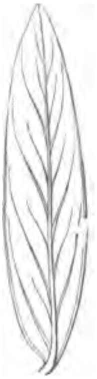
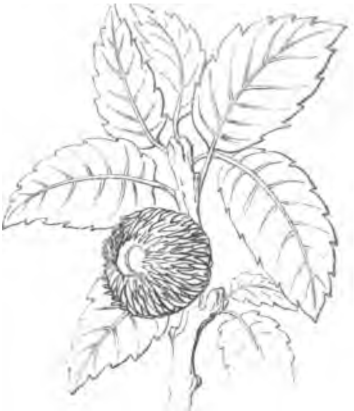


Fig. 255.



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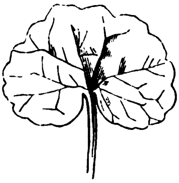


Fig. 256.

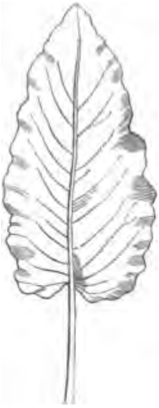


Fig. 258.

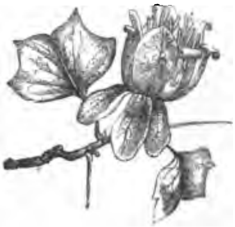


Fig. 259.

173. *Simple Leaves.*—These, although formed of one piece, may have their blades variously divided, provided the separate portions are

Fig. 254. Emarginate leaf of a species of Senna. The leaf in its contour is somewhat obovate, or inversely egg-shaped, and its base is oblique.

Fig. 255. Lanceolate leaf of a species of Senna. It is oblique at the base.

Fig. 256. Leaf of Ground Ivy *(Nepeta Glechoma)*, having a kidney-like form, and hence called reniform. Its margin is crenate. The venation is radiating.

Fig. 257. Branch of Great prickly-cupped oak *(Quercus Ægilops* or *Valonia).* The leaves are feather-veined, and have a serrated margin. The cup of the acorn is large and prickly. It is one of the oaks found in Palestine, and is probably included in the Hebrew *Allon*, which occurs in Gen. xxxv. 8; Josh. xix. 33; Is. ii. 13, vi. 13, xliv. 14; Hos. iv. 13; Amos ii. 9; and Zech. xi. 2.

Fig. 258. Undulated petiolate leaf of Rumex Patientia. The leaf is oblong-ovate, and cordate at the base, while its margin is wavy, sinuous, or crisp.

Fig. 259. Flowering branch of the Tulip-tree (*Liriodendron tulipifera*). Its leaves are truncate or abrupt, ending in nearly straight transverse lines, as if they were cut across at the apex.

not supported on stalks, nor articulated to the petiole, nor to the midrib (Figs. 258, 263, 264). In their very young state they are entire or

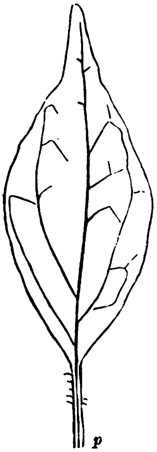
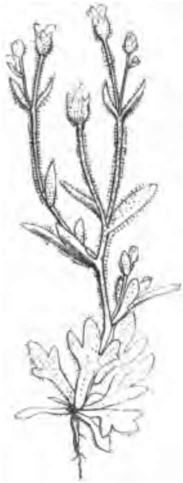


Fig. 260.



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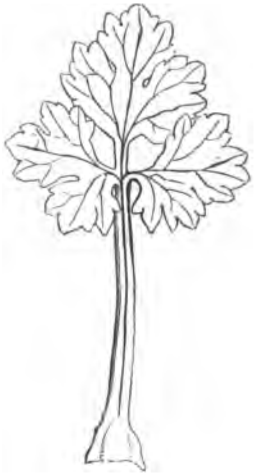


Fig. 262.

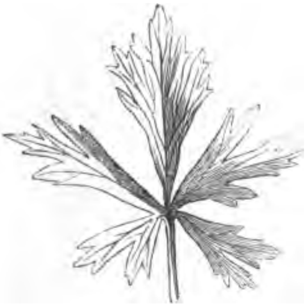


Fig. 263.

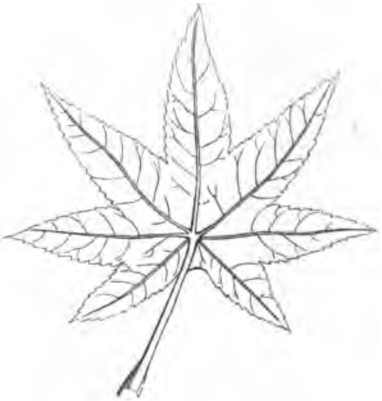


Fig. 264.

Fig. 260. Acuminated leaf of Pellitory *(Parietaria).* The leaf has an elliptical form, and is drawn out at the apex into a long point. The blade is marked *l*, the petiole, *p*.

Fig. 261. A species of Saxifrage (*Saxifraga tridactylites*), having the radical leaves trifid. The leaves are cuneate, or wedge-shaped, as regards their general form.

Fig. 262. Tripartite leaf of Ranunculus. Each of the segments is lobed, and toothed at the margin. The petiole is dilated at the base. Venation radiating.

Fig. 263. Five-partite leaf of Aconite. Such a leaf is sometimes called palmi-partite, palmately-partite, or dissected. The venation is radiating, and the segments of the leaf are narrow, and each of them is cleft and toothed at the apex.

Fig. 264. Leaf of Castor-oil plant (*Ricinus communis*). It is palmately-cleft, and exhibits seven lobes at the margin. The petiole is inserted a little above the base, and hence the leaf is called peltate or shield-like.

undivided, and equally developed. When they increase more on one side than on the other, they become either oblique, as in the Begonia and Lime (Fig. 231, p. 105), or slightly unequal at the base, as in Senna (Figs. 252-255); and when the cells and vessels increase and elongate, only at certain points, divisions take place in the margin of the leaves, and in the substance of their laminæ (Figs. 264, 267, 268).

174. In the circumscription or margin of the leaf, the following varieties occur:—*Entire*, without any divisions (Figs. 252 to 255); *crenate*, with superficial rounded divisions (Fig. 256); *serrate*, with acute points, arranged like the teeth of a saw (Fig. 247, p. 111, and Fig. 257); *dentate*, with similar pointed projections, not arranged in a saw-like manner (edges of Fig. 297, *b*, p. 128, and Fig. 327, p. 139); *repand* and *undulated*, when the margin is wavy and sinuous, or, as it is often called, crisp, as in curled dock, and other curled leaves (Fig. 258); sometimes, as in the Holly (Fig. 248, p. 112), the leaf is undulated, with spiny teeth. When the apex of a leaf is blunt and rounded, it is called *obtuse* (Fig. 253); when sharp, and forming an acute angle, it

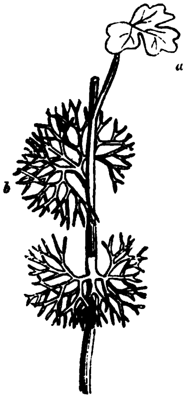


Fig. 265.

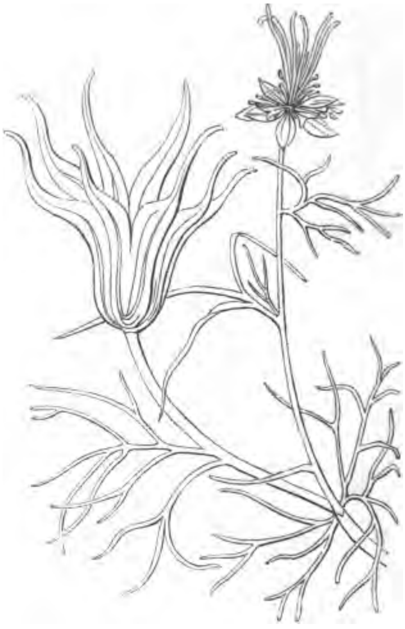


Fig. 266.

Fig. 265. Leaves of water Crowfoot (*Ranunculus aquatilis*). *a*, Three-lobed floating leaf. *b*, Filiformly dissected submerged leaves. The venation is radiating. In the submerged leaves the segments are very narrow, and called capillary or hair-like.

Fig. 266. Flowering stalks of Nigella sativa, with filiformly dissected leaves, having capillary segments. The venation is radiating. The plant is supposed to be the *Ketzach* of Scripture, translated fitches, in Is. xxviii. 25, 27.

is *acute* (Fig. 234, p. 106). The apex is *abrupt* or *truncate*, when it is terminated by a straight transverse line, as in the Tulip tree (Fig. 259); *retuse*, when it is rounded and slightly depressed; *emarginate*, when there is a deficiency or notch at the apex (Fig. 254); *obcordate*, when the deficiency is very evident, and the lobes large, so as to resemble an inverted heart on cards. When the apex is drawn out into a long point, as in Ficus religiosa, and Pellitory, the leaf is *acuminate* or pointed (Fig. 260); when the apex is blunt, and presents a stiff hard point, it is *mucronate* (Fig. 297, *a*, p. 128).

175. When the substance of the lamina is divided to about the middle, the terms *cleft* (in composition *fid*) and *lobed* are applied; and when the division extends to near the base or midrib, the term *partite* is used. These divisions, occurring in a radiating-veined leaf, give origin to the terms, *bifid* (twice cleft), *trifid* (thrice cleft), as in the leaves of some saxifrages (Fig. 261), *quinquefid* (five cleft), and *multifid* (many-cleft); also to the terms *bilobate* (two lobed), *trilobate* (three lobed) as in the floating leaves of water Crowfoot (Fig. 265, *a*), &c., when the divided portions of the leaf are large; and *tripartite* (Fig. 262), *quinquepartite* (Fig. 263), and *multipartite*, when the divisions extend to the base; *palmate* (like the palm of the hand),

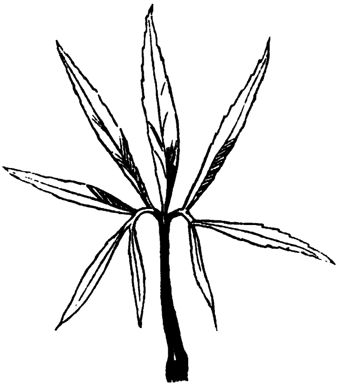


Fig. 267.

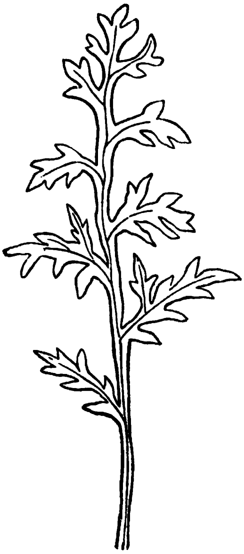


Fig. 268.

Fig. 267. Pedate leaf of stinking Hellebore (*Helleborus fœtidus*). The venation is radiating. It is a palmately-partite leaf, in which the lateral lobes are deeply divided. When the leaf hangs down it resembles the foot of a bird, and hence the name.

Fig. 268. A Pinnati-partite leaf of a species of Poppy. The leaf is feather-veined, and the divisions take place laterally to near the midrib. The segments are pinnatifid, and pinnati-partite. The leaf may be called bipinnati-partite.

when there is a broad lamina, divided into five parts, as in some species of Passionflower, in palmate Rhubarb, and in the Vine (Fig. 152, p. 64); *palmatifid*, or *palmately cleft*, when the divisions are more than five, as in Castor oil (Fig. 264, p. 117). The terms palmate and palmatifid are, however, often used indiscriminately to mark a leaf having a broad portion like the palm of the hand, and either five or more lobes. When the parts of a palmatifid leaf are narrow, like the fingers, the term *digitilobed*, *digiti-partite*, and *dissected*, are applied; and when they are cut into thread-like divisions, as in the submerged leaves of Ranunculus aquatilis (Fig. 265, *b*), and in Nigella arvensis (Fig. 266) they are said to be *filiformly dissected*. The term *pedate* (like the foot of a bird) is applied when the lateral divisions of a three-lobed leaf are again divided, as in stinking Hellebore (Fig. 267).

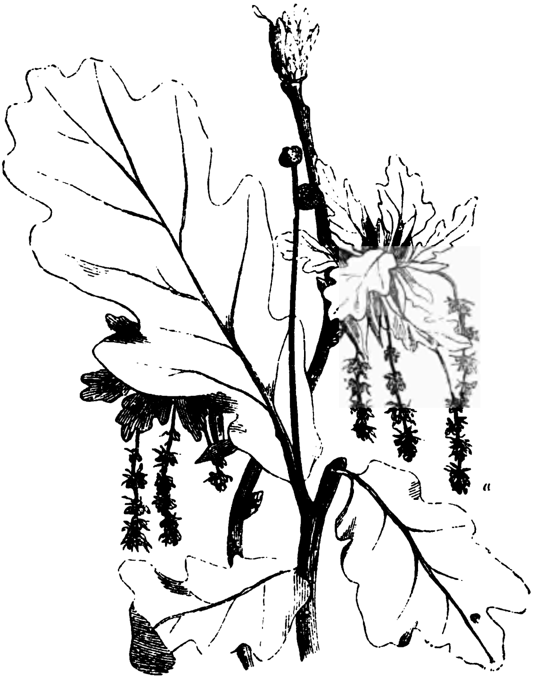


Fig. 269.

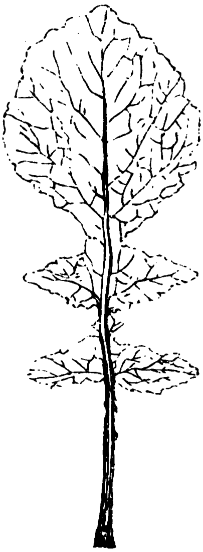


Fig. 270.

176. In a feather-veined leaf similar divisions give origin to the terms *pinnatifid*, with large lateral divisions, as in the Oak (Fig. 269);

Fig. 269. Branches of Oak (*Quercus pedunculata*), shewing pinnatifid leaves, and male flowers, *a*, in catkins (amenta). The female flowers forming acorns are attached to a long peduncle.

Fig. 270. Lyrate leaf of Turnip (*Brassica Rapa*). It is a simple leaf with reticulated venation, in which the terminal lobes are united, so as to make the leaf resemble an ancient lyre. When the lateral divisions of such a leaf become leaflets articulated to the petiole, then the leaf is compound, and is said to be lyrately-pinnate.

pectinate (comb-like), with very narrow divisions; *pinnatipartite*, when the divisions extend to near the midrib (Fig. 268); *pinnately-divided*, when the divisions extend to the midrib. When the primary divisions of such leaves are again subdivided in a similar way, the terms *bipinnatifid* and *bipinnatipartite* (Fig. 268) are applied; and when not only the primary, but also the secondary segments are divided in a similar way, the terms *tripinnatifid* and *tripinnatipartite* are used. In a pinnatifid leaf it sometimes happens that there are few divisions, in consequence of the lobes at the apex or base being united, thus giving rise to the *lyrate* leaf (like an ancient lyre), with a large terminal lobe, and segments becoming smaller as they approach the petiole (Fig. 270); and the *panduriform*, when the lobes have a recess or sinus between them, so as to make the leaf resemble a violin. When the divisions of a lyrately-pinnatifid leaf have acute terminations, and point downwards, as in the Dandelion, the term *runcinate* is applied (Fig. 271).

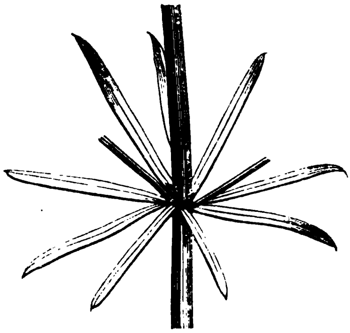


Fig. 272.

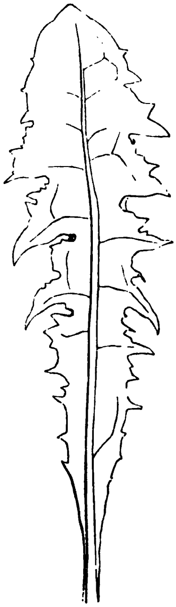


Fig. 271.

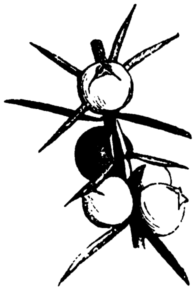


Fig. 273.

177. In the case of reticulated leaves, the angle which the veins form with the midrib, and their comparative lengths in different parts determine in a great measure the contour of the leaf. The following

Fig. 271. Runcinate leaf of Dandelion (*Leontodon Taraxacum*). It is a pinnatifid leaf, with the divisions pointing towards the petiole.

Fig. 272. Stem of Goose-grass (*Galium Aparine*), shewing verticils of linear-pointed leaves (sometimes called linear-lanceolate). The points of the leaves are bristly. Two flowering stalks have been cut across.

Fig. 273. Linear Acerose leaves of Juniper (*Juniperus communis*). The leaves end in short and hardened points like needles. The fruit is a succulent kind of cone called Galbulus.

are some of the usual terms employed:—*Linear* (Fig. 272), when the leaf is narrow, and the veins proceeding from the midrib are very short, and nearly equal. When linear leaves are sharp-pointed, as in Pines and Juniper (Fig. 273), they are called *accrose*, and the plants, on this account, are called by the Germans needle-trees (Nadel-hölzer); when linear leaves taper, so as to be like an awl, they are called *subulate;* leaves are *oblong*, when the veins from the midrib are longer than in linear leaves, but still nearly equal, and the apex is rounded (Fig. 274); *rounded* (Fig. 236, p. 107, and Fig. 313, p. 134), *oval* (Figs. 276 and 278); and *elliptical* (Figs. 277 and 279), when the veins from the centre of the midrib are longest, and the forms approach more or less to the circle or ellipse.

178. When the veins coming off from near the base are the longest, and the leaf has the shape of an egg, it is called *ovate* (Figs. 275 and 288, *a*); it is *obovate* (inversely egg-shaped) when the veins at the apex are longest, and the leaf is thus like an ovate one reversed (Fig. 254, p. 116); when the apex of an obovate leaf is straight, or not uniformly rounded, it becomes *cuneiform* (wedge-shaped), as in the lower leaves of Saxifraga tridactylites (Fig. 261, p. 117), and in the segments of the leaf of Aconite (Fig. 263, p. 117); when an obovate leaf, with a round apex, tapers to the base, as in the Daisy, it is called *spathulate;* a leaf is *lanceolate* (Figs. 255 and 280) when the veins near the base are longer than those above and below, and the leaf tapers towards the apex; *ovato-lanceolate*, when the general form is lanceolate, but the base is broad (Fig. 252, p. 115).

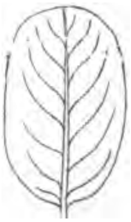


Fig. 274.

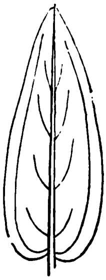
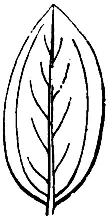


Fig. 275.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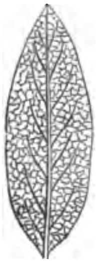
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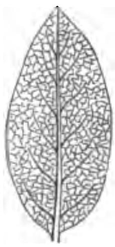
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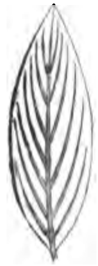


Fig. 279.

179. When the lower veins come off at an obtuse angle from the

Fig. 274. Oblong leaf of Bladder-senna (*Colutea arborescens*). It approaches to the oval form, but the ends are blunter.

Fig. 275. Ovate acute leaf of Coriaria myrtifolia, one of the adulterations of Senna. Besides the midrib there are two intramarginal ribs which converge to the apex. The leaf is therefore tricostate.

Fig. 276. Oval tricostate leaf, with an acute point.

Fig. 277. Elliptical unicostate leaf, with reticulated venation well seen. The leaf is that of Argel (*Cynanchum Argel*), one of the adulterations of Senna.

Fig. 278. Oval unicostate leaf, with reticulated venation, taken from specimens of Argel.

Fig. 279. Elliptical unicostate leaf of a Tephrosia, found among senna. The primary veins come off from the midrib at acute angles.

midrib, and are curved back so as to form with the parenchyma two large round lobes at the base, with a narrow recess or sinus, like the heart on cards, the leaf is *cordate* (Figs. 281 and 282); it is *reniform* when the recess is large, and the contour rounded, so that the leaf resembles a kidney (Figs. 256 and 283); *sagittate*, when the lobes of a cordiform leaf are acute, so as to resemble the head of an arrow, as in the Scammony plant (Fig. 284), and other species of Convolvulus (Fig. 285), as well as in Sagittaria; *hastate*, when the lower veins proceed nearly at right angles, and form two lateral narrow lobes, as in Rumex Acetosella (Fig. 286); *auriculate*, when the lobes at the base of a hastate leaf are separated from the lamina, so as to be distinct segments; *deltoid-hastate*, when a hastate leaf is short, and resembles the Greek letter delta, as in Ivy (Fig. 288, *b*). Sometimes a leaf cordate at the base (next the petiole), has a rounded contour, and it becomes *rotundato-cordate* (Fig. 287).

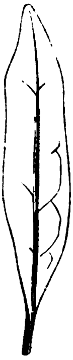


Fig. 280.

180. The lobes at the base of leaves are sometimes united more or less completely, thus giving rise to the *peltate* or *shieldlike* form, as in the Indian Cress (Fig. 289), and Castor oil (Fig. 264, p. 117), and the *orbicular* form, when the petiole is attached in the centre of a

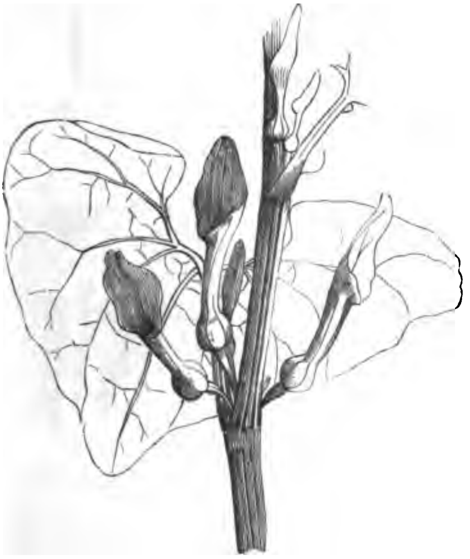


Fig. 281.

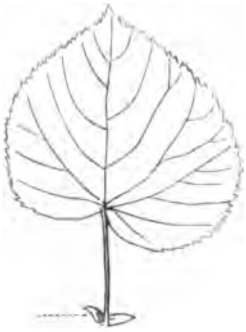


Fig. 282.

Fig. 280. Lanceolate leaf of Privet (*Ligustrum vulgare*). It is narrowed toward each extremity.

Fig. 281. Cordate leaf of Birthwort (*Aristolochia Clematitis*). The cluster of flowers arises from the axil of the leaf.

Fig. 282. Cordate leaf of Lime-tree (*Tilia*). The leaf is serrated at its margin, and its base is oblique. It may be called unequally cordate at the base.

large rounded leaf, as in Pennywort (Hydrocotyle vulgaris), and Victoria regia (Fig. 235, p. 107).

181. Very succulent leaves, with obscure veins, assume certain thickened forms, so as to become cylindrical, conical, sword-shaped, and axe-shaped. These are seen in some species of Fig-Marygold (Fig. 290, *a*).

182. The same terms are applied to all simple leafy appendages, and to the various modifications of leaves forming the parts of the flower.

183. Simple parallel-veined leaves usually have their margins entire, especially when the veins converge. They assume some of the forms already noticed, such as linear (Fig. 154, p. 65, and Figs. 291 and 292), oval, elliptical, oblong, ovate (Fig. 156, p. 65). It is comparatively rare to find any marked divisions of their laminæ. When the veins diverge at the base, or come off at obtuse angles, we meet with

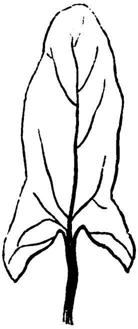


Fig. 285.

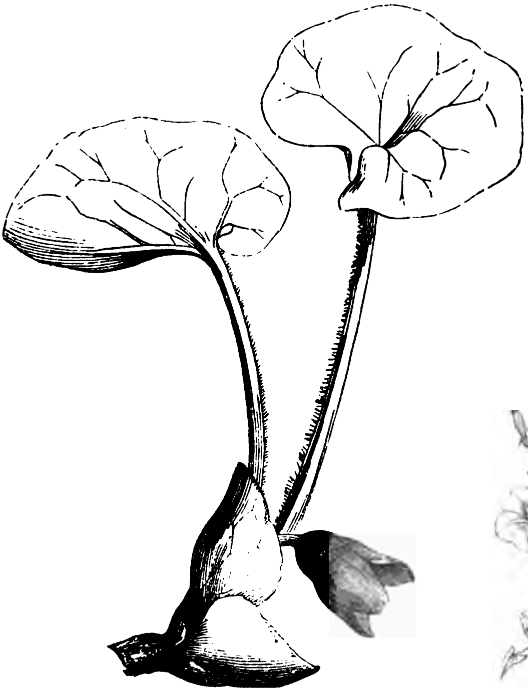


Fig 283.

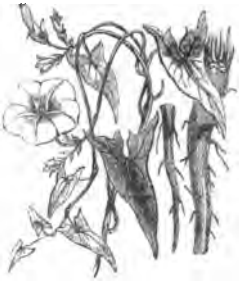


Fig. 284.

Fig. 283. Reniform (Kidney-shaped) leaves of Asarabacca (*Asarum europæum*).

Fig. 284. Sagittate (Arrow-shaped) leaves of Scammony (*Convolvulus Scammonia*). The plant is a twiner, with a large thickened root.

Fig. 285. Sagittate leaf of another species of Convolvulus. The apex is more rounded than in the Scammony plant.

hastate, sagittate (Fig. 158, p. 67), and cordate forms (Fig. 293), and their various modifications. In some Palms, where the veins running in straight lines diverge, the margin of the leaf is cut into linear segments of different lengths (Fig. 243, p. 109). In some Monocotyledons the leaves present a reticulated venation (Fig. 326, p. 139). Such plants are called Dictyogenous monocotyledons.

184. *Compound Leaves.*—These originate, like simple leaves, in the form of undivided cellular projections from the axis. When fully formed, they consist of laminæ divided down to the petiole or midrib into distinct pieces or leaflets, which are articulated, more or less distinctly, to the common stalk (Fig. 299, p. 128). These leaflets (foliola) are either supported on stalklets of their own, or are sessile. Compound leaves may be reduced to two well-marked forms; those formed by the divisions of a feather-veined unicostate leaf, and including

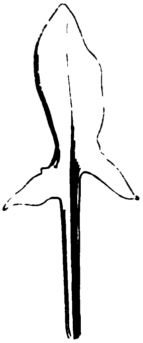


Fig. 286.

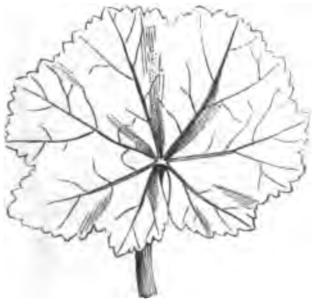


Fig. 287.

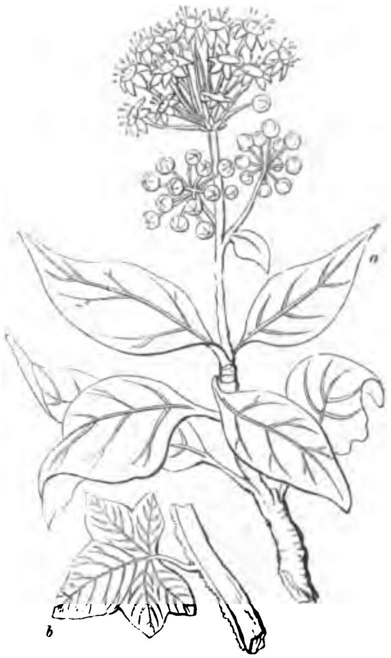


Fig. 288.

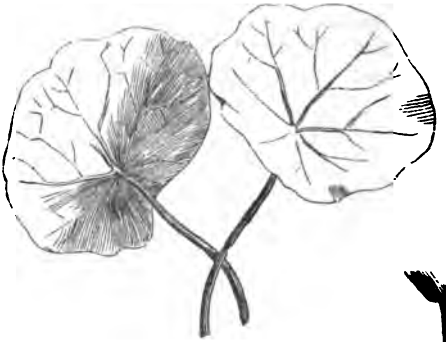
Fig. 286. Hastate (Halbert-shaped) leaf of Sheep's sorrel (*Rumex Acetosella*). The lobes at the base are in this specimen unequal.

Fig. 287. Rounded leaf of Mallow (*Malva rotundifolia*). It is cordate at the base, and is hence called rotundato-cordate. The margin is toothed and crenate.

Fig. 288. Branch and leaf of Ivy (*Hedera Helix*). The leaves, *a*, on the flowering branch are ovate acute, while the separate leaf, *b*, in the lower figure resembles the Greek Delta, and is called deltoid-hastate. It is the *Kissos* mentioned in the Apocrypha, 2 Maccab. vi. 7.

the various pinnate forms (Fig. 294); and those traced to the division of a radiating-veined multicostate leaf, including the various digitate forms (Fig. 295.)

185. When there is a distinct midrib giving off primary veins laterally, which are covered with parenchyma in such a way as to form separate articulated leaflets, the leaf is *pinnate*, as seen in Figure 294, which represents a compound leaf composed of nine pairs (juga), of shortly petiolated pinnæ, and an odd leaflet at the end. If a pinnate leaf ends in a pair of leaflets, the extremity of the midrib being



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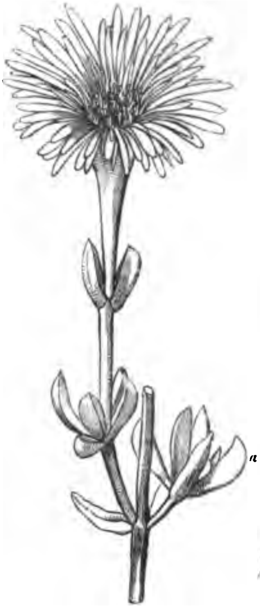

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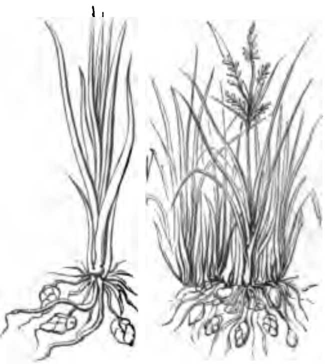


Fig. 292.

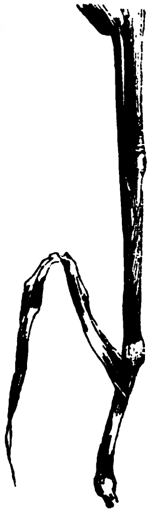


Fig. 291.

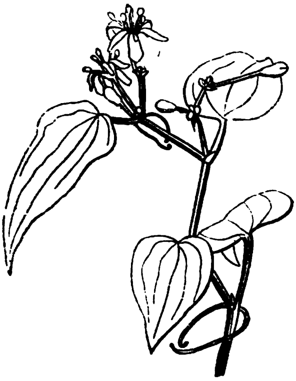
Fig. 289. Peltate (Shield-like) leaves of Indian Cress (*Tropæolum majus*). The venation is radiating, and the lobes are united at the base, so that the petiole seems to be attached above it. When the petiole is attached in the centre, the leaf is called orbicular.

Fig. 290. Falciform (scimitar-like) leaves of a species of Fig-Marygold (*Mesembryanthemum falciforme*). The leaves are fleshy and succulent.

Fig. 291. Linear leaf of wheat (*Triticum*). The venation is parallel, and the margin of the leaf is not divided. The stalk of the leaf sheathes the stem.

Fig. 292. Linear subulate leaves of a kind of reed (*Cyperus esculentus*). It is a monocotyledonous plant. It is supposed to be the Hebrew *Achu*, translated flag in Job. viii. 11.

either leafless or ending in a tendril or point, the leaf is said to be *equally* or *abruptly* pinnate (pari-pinnate), as seen in Figures 296 and



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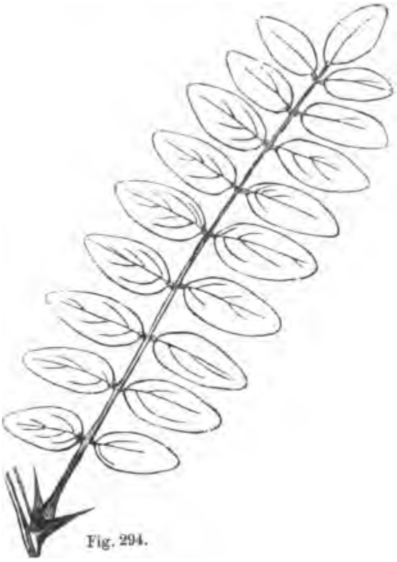

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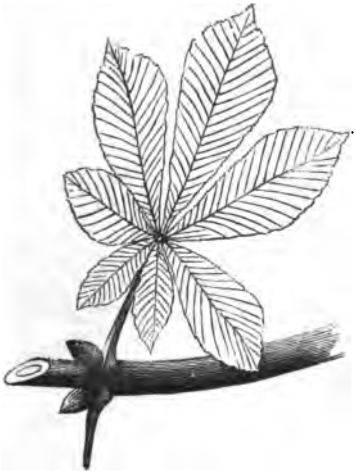

Fig. 295.

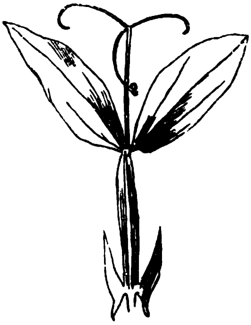

Fig. 296.

297. When there is a leaflet at the point, the leaf is said to be *unequally* pinnate (impari-pinnate), as in Figure 294. When a lyrate

Fig. 293. Cordate leaves of Smilax rudis. The leaves are multicostate, and their margins are entire.

Fig. 294. Impari-pinnate (unequally pinnate) leaf of Robinia. There are nine pairs of shortly-stalked leaflets (foliola, pinnæ), and an odd one at the extremity. At the base of the leaf stipules are seen.

Fig. 295. Septenate leaf of the Horse-chestnut (*Æsculus Hippocastanum*). Such leaves, especially when there are five leaflets, are called digitate.

Fig. 296. Pinnated leaf of Lathyrus. The petiole is winged. Two pinnæ are developed, the rest are transformed into tendrils. The leaf is said to be pari-pinnate, although, morphologically considered, it is impari-pinnate. The leaf has semi-sagittate (half arrow-shaped) stipules at the base.

leaf (Fig. 270, p. 120), becomes truly pinnate, *i. e.*, has its divisions articulated to the midrib, it is *lyrately-pinnate ;* and when the leaflets of a pinnate leaf are of different sizes, the term *interruptedly-pinnate* is applied (Fig. 298). Some parallel-veined leaves, as those of the Coco-nut, Date, and Sago Palms, are pinnate.

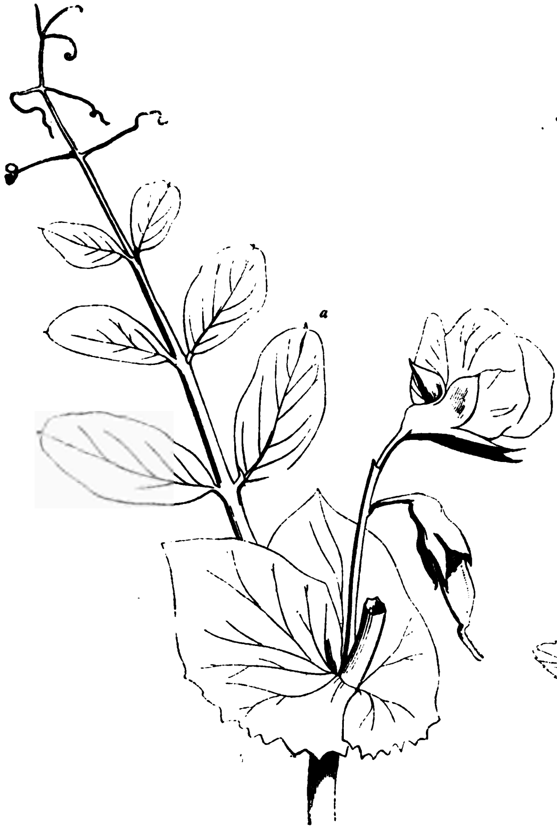

Fig. 297.

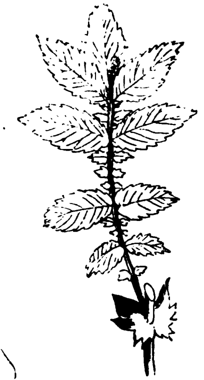

Fig. 298.

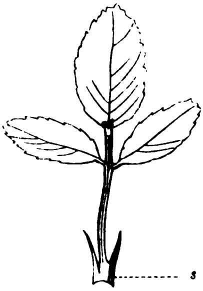

Fig. 299.

186. The number of pairs (juga) of leaflets in a pinnate leaf

Fig. 297. Flowering stem of common Pea (*Pisum sativum*), shewing an equally pinnate (pari-pinnate) leaf. There are three pairs of leaflets, and above these, three pairs of tendrils, with an odd tendril at the extremity. These tendrils are modified or transformed leaves, and therefore, morphologically, the leaf should be called impari-pinnate. At the base of the leaf there are two large stipules. The flower-stalk is two-flowered. The leaflets are mucronate, that is, blunt with a hard point.

Fig. 298. Interruptedly-pinnate leaf of Agrimony (*Agrimonia Eupatoria*). The leaflets are of different sizes, some small, others large. There are stipules at the base.

Fig. 299. Pinnate leaf of Melilot (*Melilotus officinalis*), consisting of three leaflets (pinnæ), two of which are lateral, and one terminal. The leaves do not all come off at one point, as in the ternate leaf. The leaf is sometimes said to be pinnately-trifoliolate. Adherent stipules, *s*.

varies. There may be only three leaflets (Fig. 299), in which case two are lateral, and one is terminal. Such a leaf approaches to the ternate leaf in the radiating venation (Fig. 302), and is distinguished by the distance intervening between the two articulated lateral

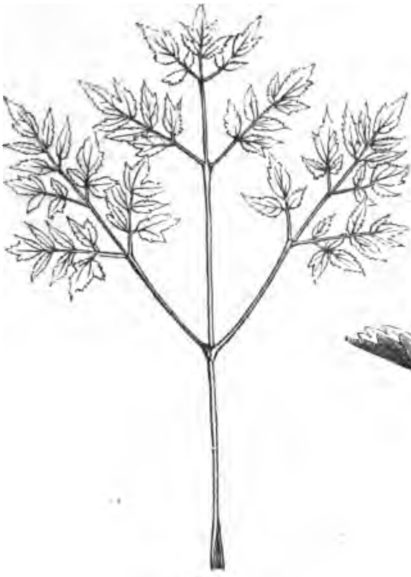
Fig. 301.

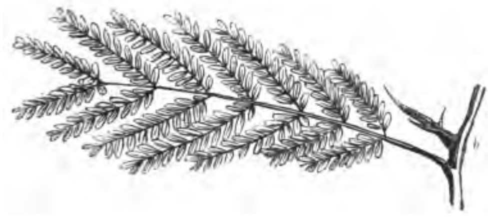

Fig. 300.

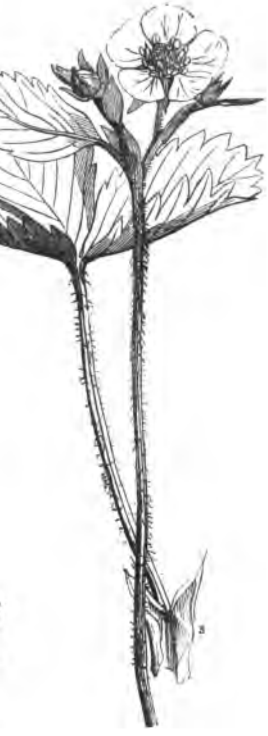

Fig. 302.

Fig. 300. Bipinnate (doubly pinnate, twice pinnate), leaf of Gleditschia triacanthos. Each of the primary pinnæ is divided into small leaflets. It may be said to be a pinnate leaf, with the leaflets also pinnate. When the small leaflets are divided the leaf becomes tripinnate, and still further divisions render it decompound. From the axil of the leaf arises a bud, *b*, which is transformed, so as to produce three spines in place of leaves. The bud is slightly extra-axillary by adhesion.

Fig. 301. Tripinnate leaf of Meadow Rue (*Thalictrum*). The primary veins coming off from the midrib are not covered with parenchyma, neither are the secondary veins, but the tertiary veins have laminæ connected with them.

Fig. 302. Ternate or digitately-trifoliolate leaf of the Strawberry (*Fragaria vesca*). The three leaflets (foliola) come from the point of the petiole. The petiole has adherent stipules *s*, at the base. The flower-stalk arises from radical leaves, and is called a scape.

pinnæ, and the terminal one. When the *leaflets* of a pinnate leaf are divided into separate pieces or pinnules, the leaf becomes *bipinnate* (twice pinnate), as in Figure 300. When the sub-division takes place to a further extent, the leaf becomes either *tripinnate* (Fig. 301), or *decompound.*

187. Compound leaves referred to the radiating venation, *i. e.*, multicostate with diverging ribs, are distinguished from those referred to the feather-venation, by the leaflets coming off from one point. When the leaflets coming from one point are two, the leaf is *binate* or *unijugate* (one pair); when three, *ternate* or *trifoliolate*, as in Wood-sorrel and Strawberry (Fig. 302); when five, *quinate* or *quinquefoliolate*, as in Hemp (Fig. 303); when seven, *septenate* or *septemfoliolate*, as in the Horse-chestnut (Fig. 295, p. 127). When the leaflets are five, the leaf is often called *digitate.* Similar forms may occur among pinnate leaves, but in them the leaflets will be seen not to come off from the point of the petiole, but at certain distances from

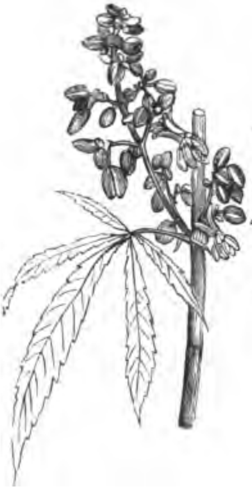
Fig. 303.

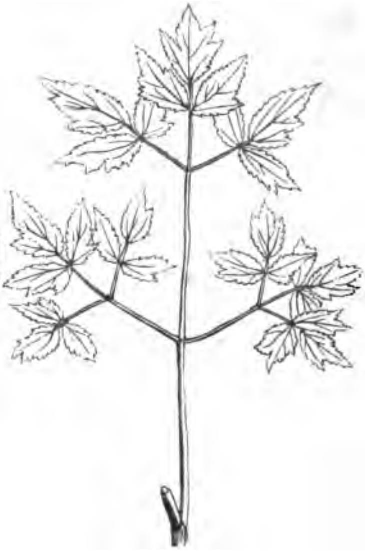
Fig. 305.

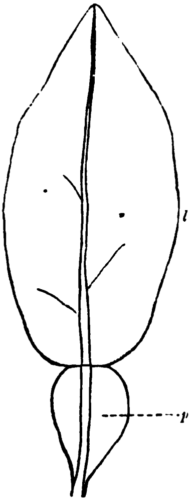

Fig. 304.

Fig. 303. Flowering branch of Hemp (*Cannabis sativa*), shewing a quinate leaf. The five leaflets arise together from the extremity of the petiole. From the axil of the leaf a cluster of male flowers springs.

Fig. 304. Leaf of the Orange-plant (*Citrus Aurantium*). The lamina, *l*, is articulated to the winged petiole, *p*. It is called a compound leaf, being looked upon as an impari-pinnate leaf, with the lateral leaflets awanting, and the terminal leaflet developed. The articulation between the petiole and lamina indicates its compound nature.

Fig. 305. Triternate leaf of Bane-berry (*Actæa*). Three primary veins come off at one point; these divide into three secondary veins; and the latter subdivide into three tertiary veins, with laminæ or parenchyma covering them.

each other. We have already seen that trifoliate compound leaves may occur in both series. Some distinguish the two forms by calling the one (Fig. 302) *digitately-trifoliolate*, and the other (Fig. 299) *pinnately-trifoliolate*. In the case of a ternate leaf, the two lateral leaflets may disappear, while the central one remains articulated to the petiole. Some consider this as being the case in the Orange leaf (Fig. 304), which is therefore looked upon as a compound leaf with a single jointed leaflet. A ternate (trifoliolate) leaf may divide in such a way as to form three leaflets on the secondary veins proceeding from each of its primary veins, and thus become *biternate* (doubly ternate); while a further sub-division, in a similar way, will render it *triternate* (triply ternate), as in Figure 305.

188. General summary of facts connected with the venation and conformation of leaves:—

1. Leaves are either netted-veined (reticulated), or parallel-veined.
2. Leaves have either a single midrib (unicostate), or several ribs (multicostate); and the latter are either radiating (spreading out from one point), or convergent.
3. Unicostate leaves have veins proceeding at different angles from various points of the midrib, and arranged more or less like the parts of a feather.
4. The conformation of leaves depends partly on the venation, and partly on the mode in which the parenchyma is developed.
5. Leaves are either simple, *i. e.*, composed of one piece, or compound, *i. e.*, composed of one or more articulated leaflets.
6. Simple leaves are either entire or divided into segments. When the divisions are superficial, they are dentate, serrate, or crenate; when the divisions are deeper, cleft or partite.
7. Simple unicostate (one-ribbed) leaves having their parenchyma cut laterally into various lobes, and so that the divisions extend to about the middle of each half of the lamina, exhibit pinnatifid, pectinate, panduriform, runcinate, and lyrate forms; when the divisions extend nearly to the midrib the form is pinnati-partite.
8. Simple multicostate (many-ribbed) leaves, with the ribs divergent, when cut longitudinally into various lobes, the divisions extending to about the middle, exhibit palmately-cleft forms; when the divisions extend to near the base, the forms are palmately-partite or dissected.
9. Simple leaves, with convergent ribs, are rarely divided deeply, and such is also the case with parallel-veined leaves, the margins of which are often entire.
10. Simple leaves, whether unicostate or multicostate, with lobes or divisions at their base, exhibit reniform, cordate, sagittate, and hastate forms; with lobes or divisions at their apex, emarginate and obcordate forms.
11. Compound unicostate leaves, having the parenchyma divided laterally into separate articulated leaflets, exhibit pinnate, bipinnate, tripinnate, and decompound forms.
12. Compound multicostate leaves, with divergent ribs, having the parenchyma divided longitudinally into separate articulated leaflets, exhibit the ternate, quaternate, quinate, and digitate forms.

4. PETIOLE OR LEAF-STALK.

189. The stalk supporting the blade of the leaf is denominated the *Petiole* (Fig. 306, *p*). It is absent in the case of *sessile* leaves (Fig. 232, p. 105); and, in certain instances, the distinction between

the lamina and the stalk is not well defined. The petiole consists of a definite number of vascular bundles enclosed in a small amount of parenchyma. The vessels are woody, dotted, spiral, and laticiferous, and they are derived from the internal part of the stem, as shewn in Figure 307, where the vessels, *fv*, surrounding the pith, *m*, are traced into the leaf-stalk, *f*.

190. At the point where the vessels leave the stem there is often a small enlargement (pulvinus), composed of cellular tissue (Fig. 307, *c*), and an articulation or joint. When the leaf dies, it separates from the stem at the joint, leaving a mark or scar (cicatrix, cicatricula) in which the ends of the different vascular bundles are seen arranged in a definite order (Fig. 308, *b*). The form of the scar, and the arrangement of the bundles, differ in different plants, and furnish, in some instances, distinct characters. The number of these vascular bundles, and their mode of distribution, determine, in some measure, the phyllotaxis and conformation of the leaves.* In the

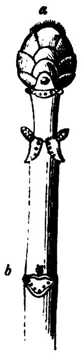

Fig. 308.

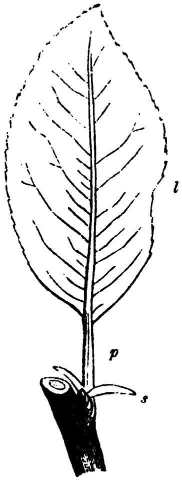

Fig. 306.

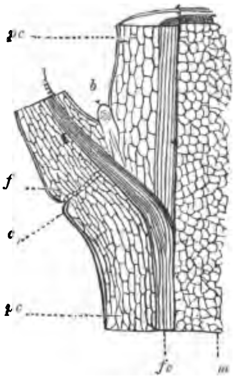

Fig. 307.

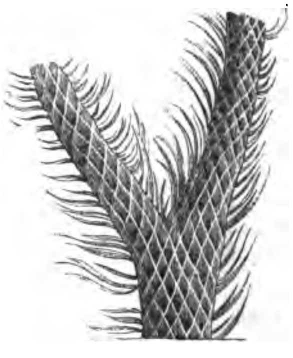

Fig. 309.

Fig, 306. Oval leaf of Pear-tree (*Pyrus communis*); *l*, lamina or blade, with primary veins coming off from the midrib, and with a serrated margin; *p*, petiole or leaf-stalk, with straight venation; *s*, stipules, or small leaves at the base of the petiole. In the axil of the leaf, *i. e.*, the angle where it joins the stem, a bud is seen.

Fig. 307. Section of a stem, and the origin of a leaf, shewing, *m*, cellular pith; *fv*, vascular bundle, which sends off a branch to the leaf-stalk; *p c*, *p c*, the parenchyma of the stem and petiole; *c*, cellular swelling at the base of the petiole, called pulvinus or cushion; above it is the articulation between the petiole and stem; *b*, bud in the axil of the leaf.

Fig. 308. Stem, with a terminal bud, *a*, and lateral bud, *b*. At the lower part is seen the scar (cicatricula), left by the fallen leaf, and in it are observed the vascular bundles.

Fig. 309. Stem of a fossil plant of the coal Epoch (*Lepidodendron elegans*), shewing scars apparently indicating the places where leaves existed. The form of the markings is characteristic of the genus, and the name is derived from their scaly appearance.

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* Lestiboudois, Phyllotaxie Anatomique, ou Recherches sur les causes organiques des diverses distributions des feuilles. Ann. des Sciences Nat. 3d ser. Bot. x. 15, 65, 136.

case of many Palms, and of Tree-ferns (Fig. 204, p. 93), the scars left by the leaves are very conspicuous; in fossil plants important characters are founded on them (Fig. 309).

191. When there is no articulation between the petiole and the stem, as is the case with many Endogens, the leaf is continuous with the axis, and is not deciduous, but withers on the stalk. In many Liliaceous plants (Fig. 90, p. 38), Orchids (Fig. 143, p. 60), and grasses (Fig. 291, p. 126), the leaves during their decay continue attached to the plants. In compound leaves there is usually an articulation, where the leaflet or leaflets join the petiole (Figs. 310 and 311). At this joint also a cellular swelling (struma) occurs. In many pinnate leaves, as those of the Sensitive plant (Fig. 312), the axial and foliolar joints and swellings (pulvinus and struma), are very evident, and appear to be connected with the folding of the leaflets under certain conditions. In ternate leaves, such as those of the Wood-sorrel, similar swellings are often seen. Where the petiole joins the blade its vessels diverge, so as to form the ribs and veins—the vascular bundle which continues in the direction of the stalk being the midrib. The epidermis of the petiole has few stomata.

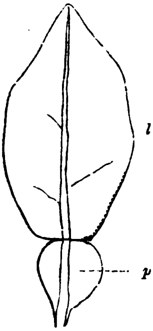

Fig. 310.

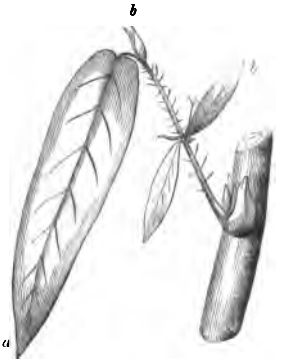

Fig. 311.

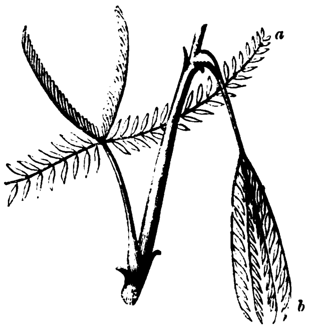

Fig. 312.

192. The petiole is usually either round, or half cylindrical, with a flattening or grooving on the upper surface. In the Aspen (Fig. 313), it is compressed laterally, or at right angles with the blade, and

Fig. 310. Leaf of Orange (*Citrus Aurantium*), shewing a winged petiole, *p*, which is articulated to the lamina, *l*. It is considered a compound leaf, having only one leaflet.

Fig. 311. Compound leaf of moving plant of India (*Desmodium gyrans*). There is a swelling (pulvinus), where the leaf-stalk joins the stem, and another swelling (struma) at the base of each of the leaflets. The leaf is unequally pinnate. The odd leaflet, *a*, at the end is large, the two pairs of pinnæ, *b*, *b*, are small. The latter exhibit evident movements. Stipules are seen close to the pulvinus at the base of the leaf-stalk.

Fig. 312. Branch and leaves of the Sensitive plant (*Mimosa pudica*). There are distinct joints and swellings at the base of the petiole, and at the base of each pinna. The leaf is bipinnate, and exhibits distinct movements when touched. Some look upon the leaf as a digitate one, with four pinnate leaflets. Stipules, with pulvinus, are seen at the points where the leaf-stalks join the stem. Leaf partially expanded, *a*. Leaf folded, with depressed petiole, *b*.

hence the trembling of its leaves from the slightest breath of air. When the leaves of a plant float on water, the petiole is sometimes distended with air cavities, as in the Water Chestnut (Fig. 314). The edges of the petiole in plants such as the Orange (Fig. 315), the Quassia plant (Fig. 316), Venus' Fly-trap (Fig. 237, p. 107), and the Sweet Pea, and other species of Lathyrus (Fig. 296, p. 127), are bordered by a leaf-like expansion called a *wing*, and hence they are denominated *winged* or *bordered* petioles. Such leaf-stalks are occasionally united to the axis for some extent, and thus become *decurrent*. In many Endogens, especially grasses, the leaf-stalk forms a *sheath* round the stem (Fig. 317); this sheath in grasses terminates at the upper part, in a process called a *ligule*, as seen in Figure 317, where *g* is the sheath (vagina), *l* the blade of the leaf, and *lig* the ligule. In Umbelliferous plants the petiole is expanded, and forms a conspicuous sheath round the stem (Fig. 318). This sheathing portion of the petiole is formed by the divergence of the vascular bundles on either side. The vessels thus surround the stem, and are covered with parenchyma. This petiolary sheath may be considered as a modification of stipules.

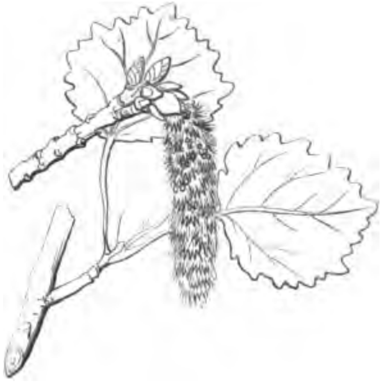

Fig. 313.

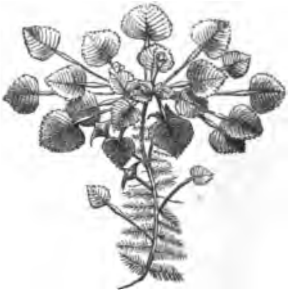

Fig. 314.

193. In some Australian plants belonging to the genera Acacia and Eucalyptus, the petiole is flattened, and becomes a foliar expansion, which occupies the place of true leaves. Such petioles have received

Fig. 313. Leaves and flowering branch of the Aspen (*Populus tremula*). The petiole is flattened laterally, and allows the leaves to move easily in the wind. Hence the plant is called trembling Poplar. The leaves are round and toothed at the margin. It appears to be one of the plants included in the terms *Baca* and *Becaim*, and translated Mulberry trees in Scripture (2 Sam. v. 23, 24; 1 Chron. xiv. 14, 15; also Psalm lxxxiv. 6). "The sound of a going on the tops of the Mulberry trees," is considered as referring to the mobility of the Poplar leaves. The flowers are in a catkin.

Fig. 314. Plant of Water-chestnut (*Trapa natans*). The submerged leaves are much divided; those which float have inflated petioles, containing numerous air cells. The swelling below the blade of the leaf indicates the situation of the air cavities.

the name of *Phyllodia*. The trees bearing them give a peculiar character to some forests in New Holland. These phyllodia are usually placed vertically, presenting their edges to the sky and earth, and their venation is parallel. They occasionally bear pinnate or bipinnate laminæ, and in such cases they are frequently much narrowed in their dimensions. In Figure 319 a bipinnate leaf is represented, with its flattened petiole or phyllodium, the venation of which is straight. On the same tree may be seen naked and leaf-bearing phyllodia. By this, as well as by their venation, their petiolary character is determined. Trees producing naked vertical phyllodia only have a singular effect as regards light and shade. Travellers have noticed this in some of the Australian forests. Some shrubby species of Wood-sorrel exhibit phyllodia, which are either naked, or bear ternate leaflets.

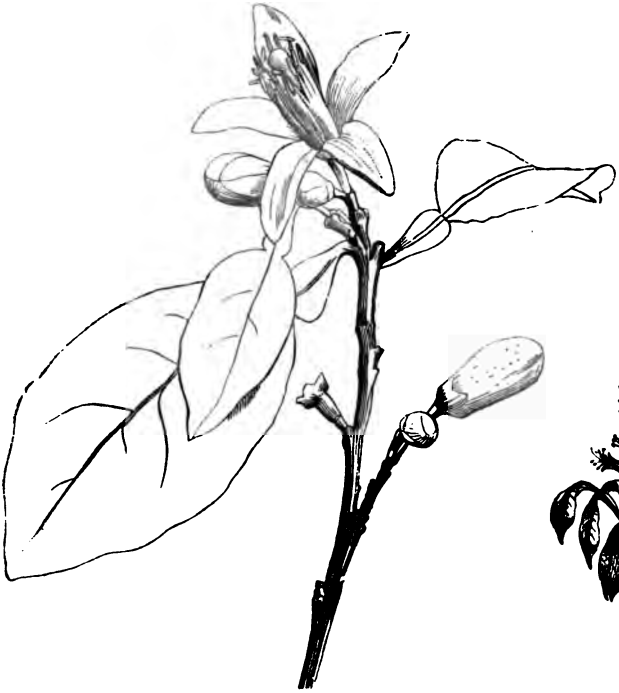

Fig. 315.

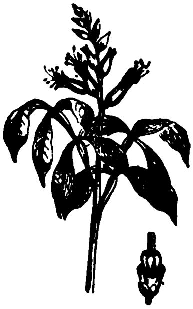

Fig. 316.

Fig. 315. Branch of Orange-tree (*Citrus Aurantium*). The leaves exhibit winged or bordered petioles, united to the lamina by a joint. They are compound leaves, with a single leaflet connected with each petiole. The flowers are shewn both in bud (imbricate æstivation), and fully expanded, with the five petals spread out.

Fig. 316. Flowering branch of Quassia plant (*Quassia amara*). The leaves are impari-pinnate, and the petiole is winged. The flowers are arranged in a raceme. The young fruit, consisting of five drupes united, is seen in a separate Figure below.

These phyllodia are often placed like leaves with their flat surfaces towards the sky and the earth. The peculiar narrow leaves which occur in certain species of Ranunculus and Bupleurum may be considered as petioles of this nature not producing laminæ.

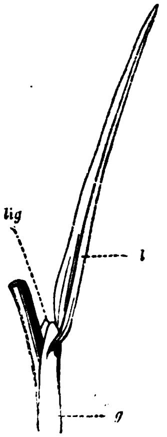

Fig. 317.

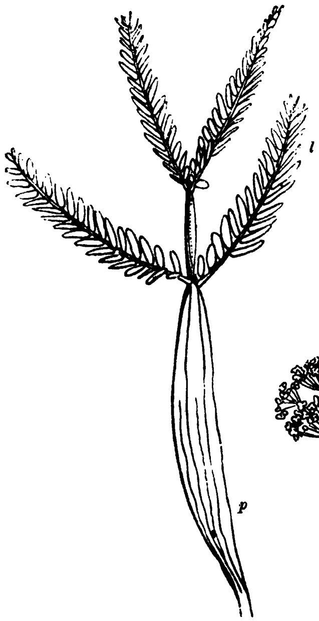

Fig. 319.

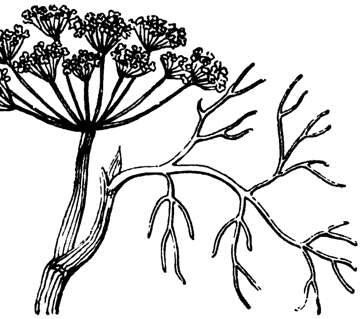

Fig. 318.

Fig. 317. Stem of a grass (*Poa*) with leaf. The sheathing petiole, *g*, ending in a process, *lig*, called a ligule; the blade of the leaf, *l*.

Fig. 318. Flowering stalk of Dill (*Anethum graveolens*). The leaf is divided into linear segments, and the petiole is broad and sheathing, and ends in two projecting processes at the base of the divided lamina. In the case of this and other umbelliferous plants, the leaf stalk sometimes receives the name of Pericladium. The flowers are arranged in a compound umbel. The plant is the *Anethon* mentioned in Matth. xxiii. 23, and translated anise.

Fig. 319. Leaf of an Acacia (*Acacia heterophylla*), from the island of Bourbon, shewing a flattened leaf-like petiole, *p*, called a phyllodium, with straight venation, and a bipinnate lamina, *l*. In many Acacias the laminæ are awanting, and phyllodia only are produced. On that account the name of leafless Acacias has been given.

5. STIPULES OR STIPULARY APPENDAGES.

194. Stipules are leafy appendages situated at the base of the petiole, and having normally a lateral position as respects the leaf. They have usually the same structure as leaves, and, in some instances, as in Lathyrus Aphaca, they constitute the only leaves which the plant produces. In the pansy (Figs. 320, 321) they are as conspicuous as the ordinary leaves. In the Pea (Fig. 297, p. 128) they are also large, and in many of the pea tribe (Fig. 296, p. 127), they assume peculiar sagittate forms. Stipules are not present in all plants. Those having stipules are called *stipulate*, those without stipules are *exstipulate*. In the classification of plants the presence and absence of stipules supply distinctive marks. At a certain stage of their growth stipules are usually larger than the leaves or leaflets produced before them. Thus they serve as a protection to the leaves in the young state, as in the India-rubber Fig, Potamogetous, Magnolias, and the Beech. These protective stipules generally fall off when the leaf expands.

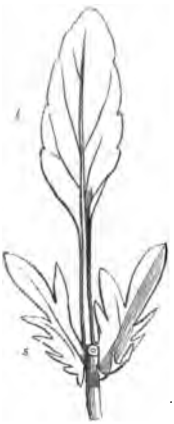

Fig. 321.

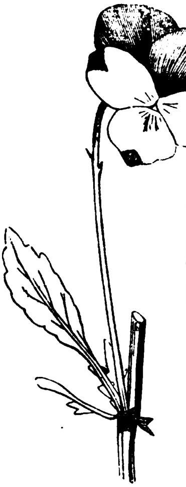
Fig. 320.

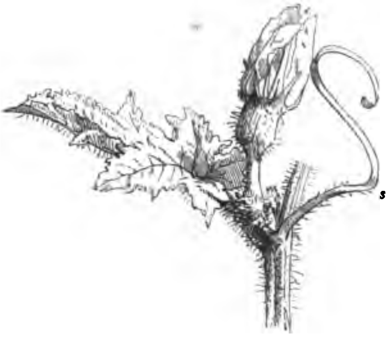

Fig. 322.

195. The form and appearance of stipules vary ; some are leaf-like (Fig. 321, *s*), others cirrhose (Fig. 322, *s*) ; some are small (Fig. 231, *s*, p. 105, and Fig. 306, *s*, p. 132), others large (Fig. 297, *b*, p. 128); some assume a scaly or membranaceous appearance, others are hard and spiny

Fig. 320. Pansy (*Viola tricolor*), shewing the ovate-lanceolate leaf, and the stipules, placed laterally at the base of the petiole. On the flowering stalk a small floral leaf (bract) is seen.

Fig. 321. Leaf of Pansy, *l*, separated from the flower; the lyrate-pinnatifid stipules, *s*, are distinctly visible, and their lateral position is seen.

Fig. 322. Melon (*Cucumis Melo)*, with its undulated leaf, and its single cirrhose stipule, *s*. The position of the tendril (Cirrhus) points out its stipulary nature. This kind of stipule is characteristic of Cucurbitaceæ.

(Fig. 294, p. 127); some are separate and free, others are united. In this way the nature of the stipules gives characters in many natural orders. In the Cinchona bark trees (Fig. 323), which have opposite leaves, the stipules unite, so as to form one on each side of the stem between the petioles, hence they are called *interpetiolar*. At the base of the stipules of Cinchona, and other allied genera, there are numerous small glands which secrete an oily and resinous matter (¶ 71, p. 46). In the Rhubarb tribe, which have alternate leaves, the stipules unite, so as to form a sheath or *ochrea* round the stem. In the Plane tree, and in the Astragalus, they unite, so as to form a leafy expansion on the opposite side from the leaf, and in the Rose tribe (Fig. 324), they are united to each other and to the petiole, thus becoming *adnate*. The petioles of many plants have a sheathing portion at their base (Figs. 318 and 325), which may be considered as adherent stipules. On this account the reticulum, or mat-like substance, at the base of the leaves of palms, is often called stipular. Besides the leaves at the base of the petiole, smaller leaflets (stipels) are occasionally produced at the base of the pinnæ of compound leaves, as in the bean.

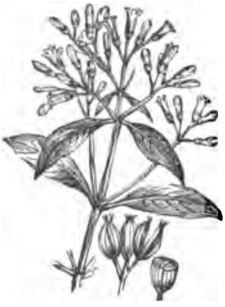

Fig. 323.

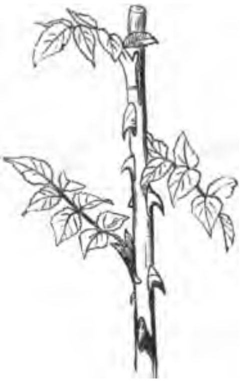

Fig. 324.

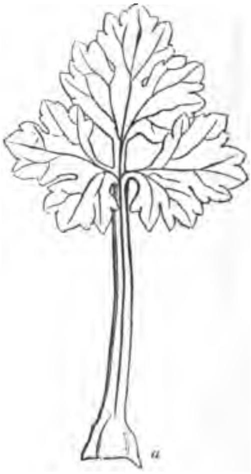

Fig. 325.

Fig. 323. A species of Peruvian bark tree (*Cinchona*), shewing opposite leaves, with inter-petiolar stipules. The flowers are in a sort of corymbose cyme, the fruit, as shewn in the lower figure, consists of two carpels united.

Fig. 324. Branch of the Rose, with adnate or adherent stipules, united to each other, and to the lower part of the petiole. They are sometimes called Petiolar. The leaves are unequally pinnate. The stem is covered with hooked aculei or prickles.

Fig. 325. Tripartite and lobed leaf of Crowfoot (*Ranunculus*), with the lower part of the petiole dilated and sheathing. The dilated portion, *a*, may represent adnate stipules.

6. TRANSFORMATIONS OF LEAVES AND THEIR APPENDAGES.

196. Some of these transformations have been already noticed, but there are others to which it is necessary to direct attention. The morphological relations between leaves, scales, and spines—between petiole and laminæ, and between stipules and petioles, have been adverted to. All these nutritive organs are sometimes changed into tendrils (cirrhi), with the view of enabling the plants to twine round others for support. In leguminous plants (the pea tribe) the pinnæ are frequently cirrhose; thus, in Figure 297, p. 128, a pea leaf is represented with three pair of cirrhose (tendril-like) pinnæ, and an odd leaflet, in the form of a tendril, at the extremity of the midrib. So also, in Figure 296, page 127, the leaf ends in three tendrils which morphologically are to be considered pinnæ. Sometimes a whole leaf becomes cirrhose, as in some species of Lathyrus. In the Vanille plant some of the leaves are frequently changed into tendrils. In Smilax (Fig. 326), there are two stipulary tendrils, while in the Cucumber tribe there is a single one (Figs. 322 and 327) at the base of each leaf. In the Passion-flower the lateral leaf-buds, and in the Vine (Fig. 153, p. 64), the terminal ones become tendrils.

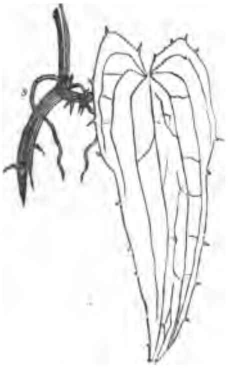

Fig. 326.

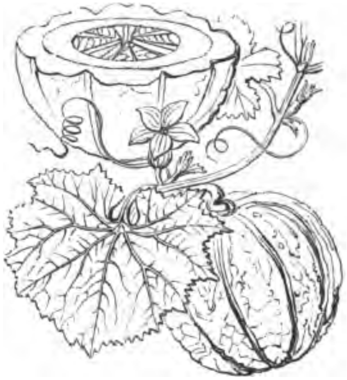

Fig. 327.

197. The leafy parts of plants are also liable to become hardened and spinescent. The leaves of some species of Astragalus and Barberry (Fig. 238, p. 107), and the stipules of the false acacia (Robinia) are spiny. In these instances the vascular bundles are developed in

Fig. 326. Leaf and petiole of Smilax, with two stipulary tendrils, *s*. The leaf is ovate, acute, and cordate at the base. The venation is reticulated, although the plant is monocotyledonous. It is denominated by Lindley Dictyogenous on that account.

Fig. 327. Flower, fruit, and leaves of the Melon (*Cucumis Melo*). The leaves are rounded, cordate at the base, the margin toothed, and the venation radiating. The stipule is transformed into a tendril. The fruit is a Pepo. The plant seems to be included in the Hebrew word *Abbatachim*, translated melons (Numbers xi. 5).

a marked degree, while the parenchyma is deficient. To the same cause is attributed the spiny margin of the Holly-leaf. In the Gooseberry (Fig. 328), the swelling (pulvinus) at the base of the petiole, and below the leaf, *f*, assumes a spinose character.

198. Changes in the appearances of leaves are produced by adhesions and foldings of various kinds. When two leaves unite at their bases, as in some species of Honeysuckle (Fig. 329), they are called *connate*, a similar appearance is produced by the partial union of two sessile leaves, as in the Caper-Spurge. When the lobes at the base of a leaf unite on the opposite side of the stem from the laminæ, a *perfoliate* leaf is the result, as seen in some species of Bupleurum, (Fig. 330), and Baptisia. The formation of peltate (Fig. 289, p. 126), and Orbicular (Fig. 235, p. 107), leaves have been traced to the union of the lobes of a cleft leaf. In the case of the Victoria leaf the transformation may be traced during germination. The first leaves produced by the young plant are linear, the second are sagittate and hastate, the third are rounded cordate, and the next are orbicular. The cleft indicating the union of the lobes remains in the large leaves.* Many forms of stipules, such as petiolar, interpetiolar, and sheathing, are traced to adhesion.

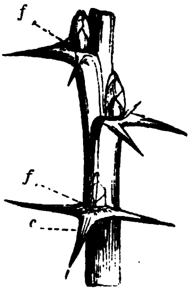

Fig. 328.

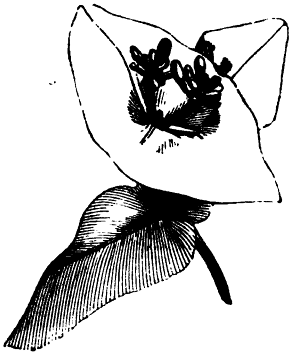

Fig. 329.

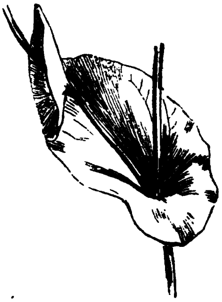

Fig. 330.

199. Folding of the leafy appendages, and union of their edges, give rise to the formation of a hollow leaf or pitcher (ascidium, ascus). In the Side-saddle flower the ascidia are considered as being formed by the petiole or phyllode, a part of which, in an unadherent state, is pro-

Fig. 328. Branch of Gooseberry (*Ribes Grossularia*), shewing the cushion (pulvinus), producing spines, *c*. These spines are considered as an altered state of the cushion. They arise below the scars of the leaves, *ff*, from the axils of which buds are produced.

Fig. 329. Connate leaves of a species of Honeysuckle (*Lonicera Caprifolium*). Two leaves are united by their bases. They are sometimes said to be confluent.

Fig. 330. Perfoliate leaf of a species of Hare's-ear (*Bupleurum rotundifolium*). The two lobes at the base of the leaf are united, so that the stalk appears to come through the leaf.

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* See Hooker, Victoria regia, or Illustrations of the Royal Water Lily. 1851.

longed upwards (Fig. 332). In the Pitcher-plant there is an evident lid, united to the pitcher by a joint (Fig. 331, *l*). The lid is looked upon as the metamorphosed lamina, articulated to the hollow petiole or phyllode. It may be said to resemble the jointed leaves of the Orange (Fig. 304, p. 130), or Dionæa (Fig. 237, p. 107), with their petioles folded so as to adhere by the edges, and their laminæ reduced in size, so as to form a lid (operculum). In the pitcher-plant we perceive transitions from a winged to a rounded, and then to a hollow petiole. Thus, in Figure 333, the petiole arising from the stem is first broad and leaf-like, then it becomes narrow and rounded, and ultimately it assumes the form of a pitcher, with the lamina in the form of a lid. In an East Indian twining pitcher-plant, called Dischidia Rafflesiana, the pitchers are considered by Griffith as formed by folded laminæ. The hollow (fistular) leaves of the onion, and of other species of allium, may be traced to the folding and adhesion of the margins of the foliar appendages.

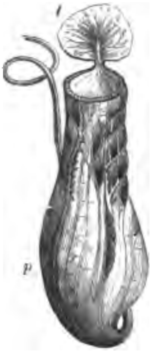

Fig. 331.

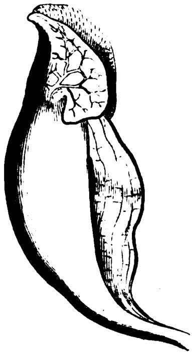

Fig. 332.

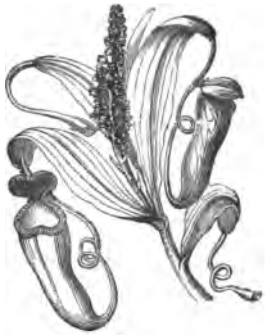

Fig. 333.

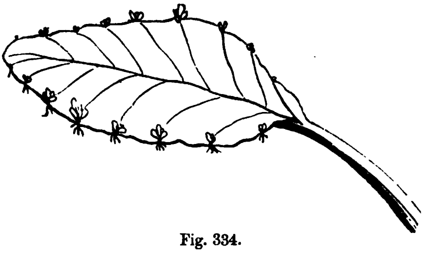

Fig. 334.

Fig. 331. Pitcher (*Ascidium, ascus*) of a species of Pitcher-plant (*Nepenthes destillatoria*). It is supposed to be formed by a folded petiole, *p*, or phyllode, the edges of which are united. The lid, *l*, at the top is supposed to represent the lamina, united by articulation to the pitcher. Part of the petiole is narrow and twisted.

Fig. 332. Pitcher (*Ascidium*) of a species of Side-saddle plant (*Sarracenia purpurea*). The pitcher is supposed to be formed by the folded petiole, which is prolonged upwards. There is no articulated lid.

Fig. 333. Flowering branch of a pitcher-plant (*Nepenthes destillatoria*). The petiole, as it arises from the stem, is broad and leafy, with straight venation; it then becomes small and round, and coils at one part of its course; ultimately it is folded on itself, and its margins unite so as to form a pitcher; at the mouth of which the lamina appears in the form of a lid or operculum.

Fig. 334. Leaf of Bryophyllum calycinum, producing buds along the margin, at the extremities of the primary veins. When placed on the surface of moist soil young plants are produced at the edges of the leaf. The leaf is called proliferous.

200. It has been already remarked, that buds and bulbils (Fig. 146, p. 61, and Fig. 163, p. 68), are produced at the points where leaves join the stem. In some instances, however, we find that buds are produced from the margins or surfaces of leaves.* In Bryophyllum (Fig. 334), this is a common occurrence, and it is met with in many plants of the order Gesneraceæ, the leaves of which, when placed on the surface of moist earth, become what is called *proliferous*, or bud-bearing. In Nymphæa micrantha buds appear at the upper part of the petiole. The leaf of Venus' Fly-trap (Fig. 237, p. 107), when cut off and placed in damp moss, with a pan of water underneath, and a bell-glass for a cover, has produced buds from which young plants were obtained. Some species of Saxifrage, and of Ferns, also produce buds on their leaves and fronds.

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* Trecul, Recherches sur l'origine des Bourgeons adventifs. Ann. des Sciences Nat. Botan. 3d ser. viii. 268.

CHAPTER III.

REPRODUCTIVE ORGANS OF FLOWERING PLANTS.

201. The flower or Floral organs concerned in the production of seed, containing the young plant, are called *Organs of Reproduction.* In Dicotyledons and Monocotyledons they are usually obvious, and hence these plants are called *Phœnogamous* or *Phanerogamous* (Fig.

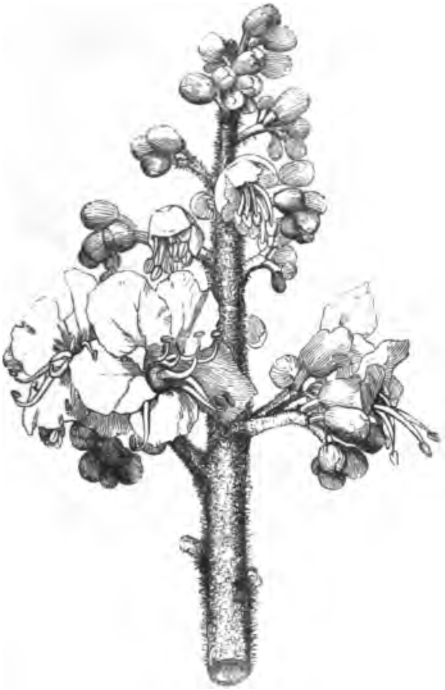


Fig. 335.

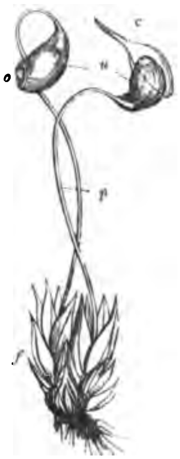


Fig. 336.

Fig. 335. Flowering branch of the Horse-chestnut (*Æsculus Hippocastanum*). The flowers and organs of reproduction are conspicuous; hence the plant is Phanerogamous, or Phænogamous. The flowers are arranged in a racemose cyme.

Fig. 336. A moss (*Funaria hygrometrica*) having no flowers, and no conspicuous organs of reproduction; hence called Cryptogamous. Leaves, *f*, connected with the fruit stalk, *p*; *u*, urn-like spore-case, with its calyptra, *c*, and operculum, *o*.

335); while in Acotyledons they are obscure, and hence the plants are called *Cryptogamous* (Fig. 336), the former being *Flowering* plants, the latter *Flowerless*.

I. THE INFLORESCENCE.

202. This term designates the arrangement of the flowers on the flowering stem or branch. Flowers are produced from flower-buds, as leaves are from leaf-buds. These two kinds of buds have a resem-

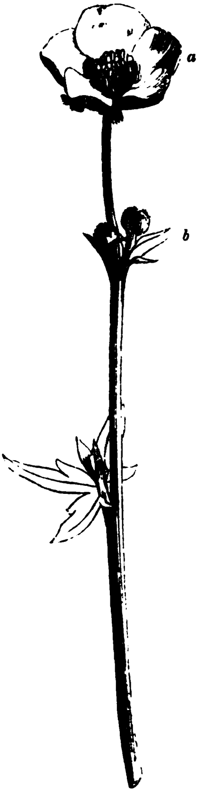


Fig. 337.

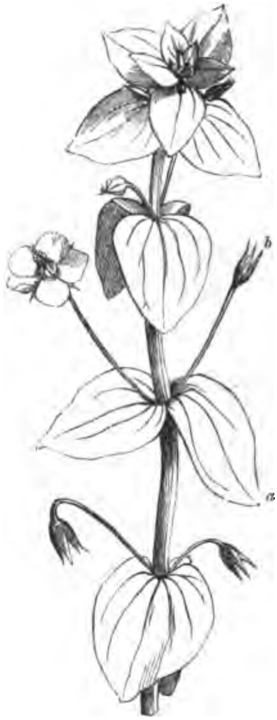


Fig. 338.

Fig. 337. Flowering stalk of Acrid Crowfoot (*Ranunculus acris*). An expanded flower, *a*, terminates the axis. The flower-buds, *b*, are produced on separate floral axes, each terminated by a single flower. The inflorescence is definite or determinate.

Fig. 338. Indefinite flowering stalk of Pimpernel (*Anagallis arvensis*). Single flowers, *b*, are produced in the axils of leaves, *a*, called Bracts or Floral leaves. The bracts resemble the ordinary leaves of the plant. The stalk continues to elongate, bearing axillary flowers. The Inflorescence is indefinite or indeterminate.

blance to each other as regards the arrangement and the development of their parts; and it sometimes happens, from injury and other causes, that the part of the axis which, in ordinary cases, would produce a leaf-bud, gives origin to a flower-bud. It will be afterwards shewn that, morphologically considered, the flower is to be looked upon as a shortened branch bearing parts analogous to leaves. The flower-bud contains either one or many flowers.

203. *Bracts.*—Like leaf-buds, the flower-buds arise either from the extremity of an axis, and are then terminal (Fig. 337), or they are produced from the axil of leaves called *bracts* (Fig. 338). These bracts are sometimes like the ordinary leaves (leafy or leaf-like bracts), as in

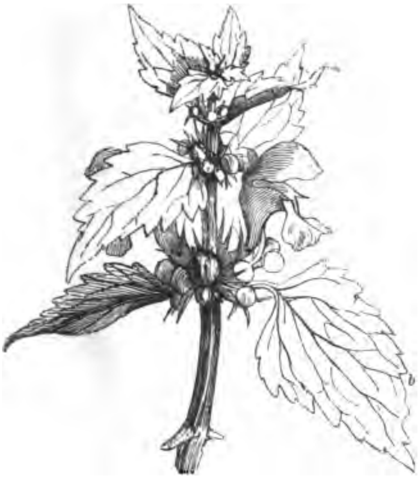


Fig. 339.

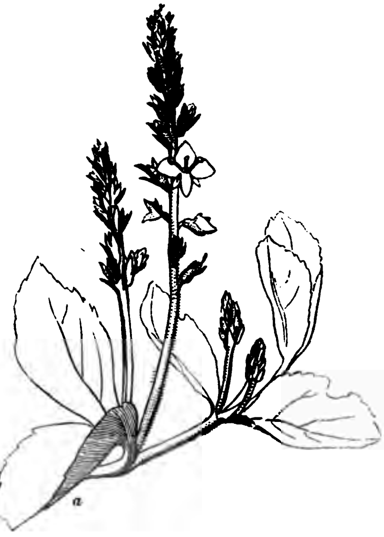


Fig. 340.

Fig. 339. Flowering stalk of the White Dead-nettle (*Lamium album*). The Bracts, *b*, are like the ordinary leaves of the plant, and produce clusters of flowers in their axil. The clusters are called Verticillasters, and consist of flowers which are produced in a centrifugal manner, the central one expanding first. Hence the Inflorescence is definite. The flowering stalk continues, however, to elongate in an indefinite manner.

Fig. 340. Branch of a kind of Speedwell (*Veronica officinalis*). The flowering stalks are produced in the axil of ordinary leaves, *a*, called Bracts. The flowers are in racemes, and at the base of each flower is a small leaf called a bracteole or bractlet. The Inflorescence is indefinite or indeterminate.

many species of Speedwell, Periwinkle, and Pimpernel (Fig. 338),

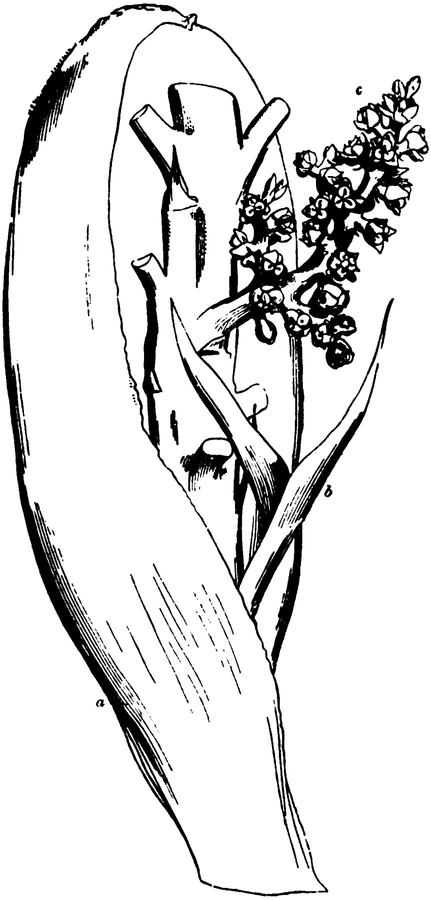


Fig. 341.

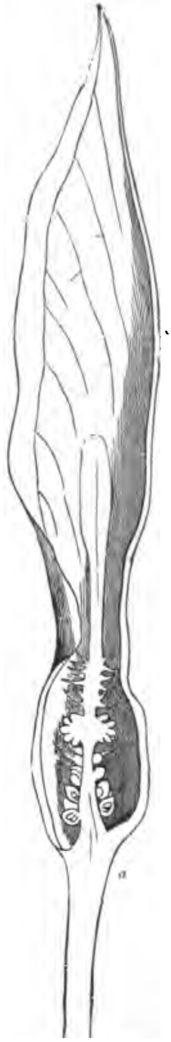


Fig. 342.

where they bear single flowers, and in the common Bugle, Dead-nettle

Fig. 341. Flowering stalk of a Fan-palm (*Chamærops*). The flowers are produced on a spadix, *c*, or succulent spike, which is in this case branched, and all are enclosed in a sheathing bract, *a*, called a Spathe. Besides the general sheathing bract, there are others of a partial nature, *b*. Large specimens of Palm spathes are in the Museum of the Ed. Botanic Garden.

Fig. 342. Flowers of Cuckow-pint (*Arum maculatum*), cut vertically, shewing the succulent spadix continuous with the stalk, *a*, covered with sessile flowers, the lower female, the upper male, and the large sheathing bract or spathe, *b*. The spadix terminates in a succulent club-shaped cellular mass.

(Fig. 339), and some species of Veronica (Fig. 340), where they produce several flowers. They have the colour of leaves in such instances, and consist of cells and vessels, similarly arranged, in the form of parenchyma, ribs and veins, with epidermis and stomata.

204. Bracts, however, in many plants, as regards colour, size, and form, present a different appearance from leaves. In Amherstia nobilis, and in some species of Salvia, they are large, and of a fine scarlet colour, so as to give a marked character to the flowers. In Palms (Fig. 341, *a*), and in species of Arum (Fig. 342, *b*), the bracts are large and sheathing, and are called *spathes;* they enclose numerous flowers, supported on a common succulent stalk (spadix). In some South American Palms, such spathes enclose upwards of 200,000 flowers, and they are sometimes twenty feet long. In the species of Narcissus (Fig. 343), and Snowflake (Fig. 344, *b*), sheathing bracts are seen. In Grasses, the bracts constituting the outer covering of the spikelets of flowers are called *glumes* (Fig. 345, *gl*).

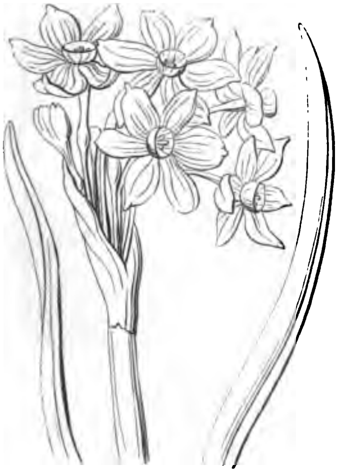


Fig. 343.

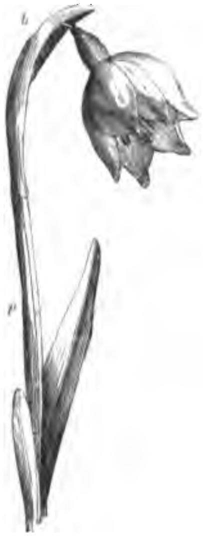


Fig. 344.

205. In the case of numerous flowers on a common stalk, the bracts are often numerous also, and are arranged in a whorl or *involucre*, as it is called. An assemblage of involucral bracts is seen in

Fig. 343. Flowers of Polyanthus-Narcissus (*Narcissus Tazetta*), bursting from a sheathing bract. The common flower-stalk is called a scape, and the flowers are supported on partial stalks called pedicels. The inflorescence is umbellate and cymose. The plant is supposed to be the *Chabazzeleth* of Scripture, translated Rose (Song of Solomon ii. 1; Is. xxxv. 1.)

344. Flower of spring Snow-flake (*Leucojum vernum*), supported on a peduncle, *p*, called a scape, and coming out from a sheathing bract, *b*. The flower is drooping and solitary, and the perianth is above the ovary.

composite flowers, such as the Daisy, Dandelion, and Marygold (Fig. 346), and in umbelliferous plants, such as Hemlock and Cummin (Fig.

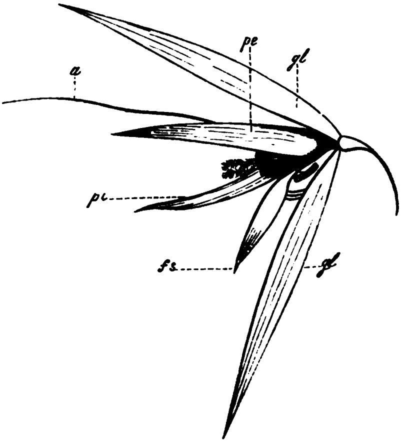
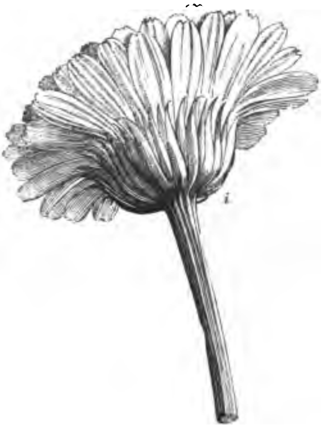


Fig. 345.



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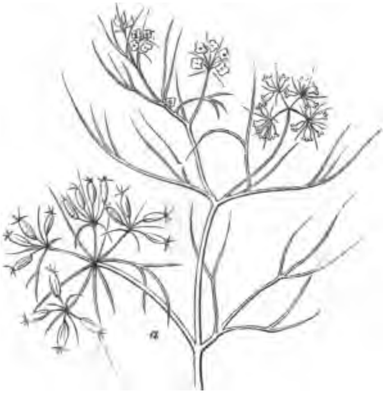

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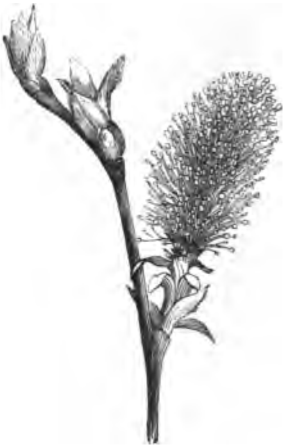


Fig. 348.

Fig. 345. Spikelet of Oat (*Avena sativa*) laid open, shewing the bracts, *gl*, *gl*, which are denominated Glumes; *p e*, the outer pale or glumellule, with a dorsal awn, *a*; *p i*, the inner pale; *f s*, an abortive flower. The two pales (*paleæ*, *glumellulæ*) enclose the essential organs of reproduction.

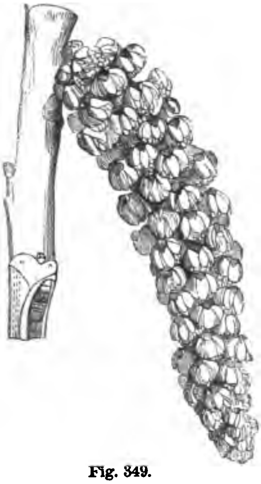
Fig. 346. Head (Capitulum) of Marygold (*Calendula*), shewing a congeries of flowers, *f*, enclosed by rows of bracts, *i*, at the base, which are collectively called an Involucre.

Fig. 347. Umbels of the Cummin plant (*Cuminum Cyminum*). The leaves are cut into filiform segments. At the base of the general umbel there are cut leaves (bracts), which form the general or universal involucre, and at the base of the smaller umbels (umbellules) other narrow leaves are seen forming the partial involucre. The plant is the *Cummin* or *Kammon* of the Old Testament (Is. xxviii. 25, 27), the *Kuminon* of the New Testament (Matth. xxiii. 23). What are commonly called Cummin seeds are in reality the achænia, or fruit containing the seeds.

Fig. 348. Catkin (Amentum) of Willow, bearing male flowers, each of which arises from a scale (Squama), or, in other words, a scaly bract. There are numerous flowers and bracts in the catkin.

347). In the last-mentioned plant there are two rows of bracts in each head of flowers, one, *a*, denominated the general involucre, at the base of the large umbel; the other the partial involucre, or involucel, at the base of the smaller umbels, or umbellules. The bracts connected with the flowers, in the catkins of the Poplar (Fig. 313, p. 134), of the Willow (Fig. 348), the Walnut (Fig. 349), and other amentiferous (catkin-bearing) plants, are called *scales*.

206. Bracts sometimes fall off when the flowers expand, at other times they continue during flowering, and, in certain instances, they form part of the fruit. The cup (cupula) of the Acorn (Fig. 350, *a*),



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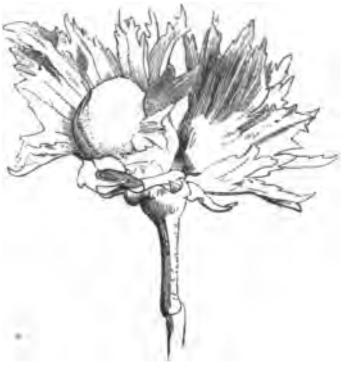

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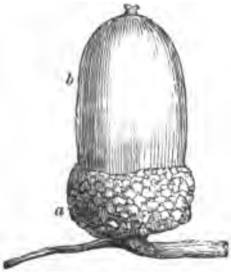


Fig. 350.

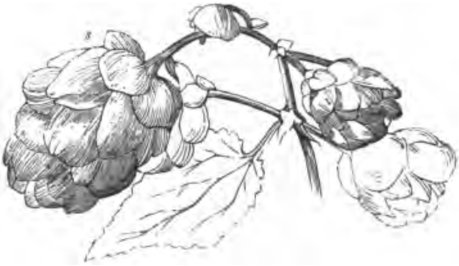


Fig. 352.

Fig. 349. Male Catkin (Amentum) of Walnut (*Juglans regia*), shewing numerous scaly bracts among the flowers.

Fig. 350. Fruit of the Oak (*Quercus pedunculata*), shewing a collection of bracts, *a*, forming the cup (cupula) of the acorn, *b*.

Fig. 351. Fruit of the Hazel (*Corylus Avellana*), shewing bracts which form the husk of the nut.

Fig. 352. Fruit of the Hop (*Humulus Lupulus*), shewing scales, *s*, which are bracts covering female flowers. The scales are arranged in a spiral manner like those of the cone. They are soft and membranous. The fruit is compound or anthocarpous, and is called a Strobilus.

and the husk of the Hazel-nut (Fig. 351) are formed by bracts; so also are the scales of the Hop-fruit (Fig. 352), of the Fir cone (Fig. 353), and of the Pine apple (Fig. 354).

207. Bracts are said to be *empty* when they do not give origin to flowers. Thus, in Salvia Horminum, the top of the flowering axis ends in a series of coloured empty bracts, and in the Pine-apple plant the fruit (Fig. 354) is terminated by a crown of leaves, which are to be considered as empty bracts, terminating the axis. The outer row of scales in the involucre of some compound flowers are empty bracts, which occasionally produce buds, as in the case of the Hen-and-chickens daisy. In Cruciferous plants, such as Wallflower, and in the Borage tribe, such as Forget-me-not (Fig. 400, p. 169), bracts are very rarely developed, and hence they are called ebracteated.

208. When an axis bearing numerous stalked flowers arises from a bract, there are sometimes smaller leaves, called *bractlets* or *bracteoles*, at the base of the small flower-stalks. Thus, in Figure 340, p. 145, the cluster of flowers arises from a bract, and each flower has a bractlet at the base of its stalk. When bracts or bractlets are placed, so as to be close to the outer envelope (calyx) of the flower, there is occasionally some difficulty in determining what parts are to be referred to each of these organs. In the Mallow tribe (Figs. 355 and 356, *e*) the outer calyx (epicalyx) seems to be of this nature. When

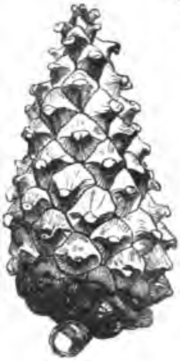


Fig. 353.

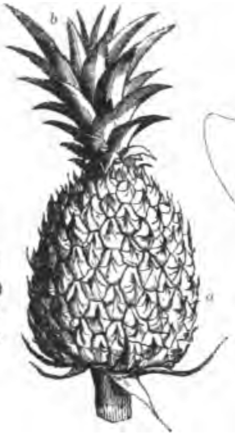


Fig. 354.

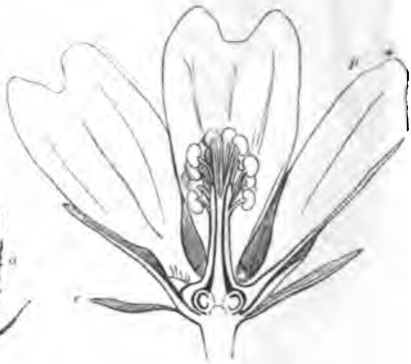


Fig. 355.

Fig. 353. Fir cone, composed of numerous scales, arranged round an axis in a spiral manner, each scale covering a female flower. The scales are hardened bracts.

Fig. 354. Fruit of Pine apple (*Ananassa sativa*), composed of numerous flowers, on a common axis, each covered by a scale or bract, *a*. The crown, *b*, of the Pine-apple may be considered as composed of a series of empty bracts, *i.e.*, bracts not bearing flowers. These bracts terminate the flowering axis.

Fig. 355. Flower of Mallow (*Malva sylvestris*), cut vertically. The Epicalyx, *e*, composed, according to some, of bracts which cover the true calyx; petals, *p*; cluster of monadelphous stamens in the centre.

bracts adhere to the flower-stalk and become decurrent, as in the Lime tree (Fig. 357, *b*), they appear like winged branches, giving origin to the inflorescence.

209. *Flower-stalk.*—The axis bearing the flower or flowers, is called the floral axis (Fig. 335, p. 143, and Fig. 337, p. 144). It is a branch coming from a flower-bud. The term *Peduncle* is that usually given to a stalk supporting a single flower (Fig. 358, *p*), or numerous flowers

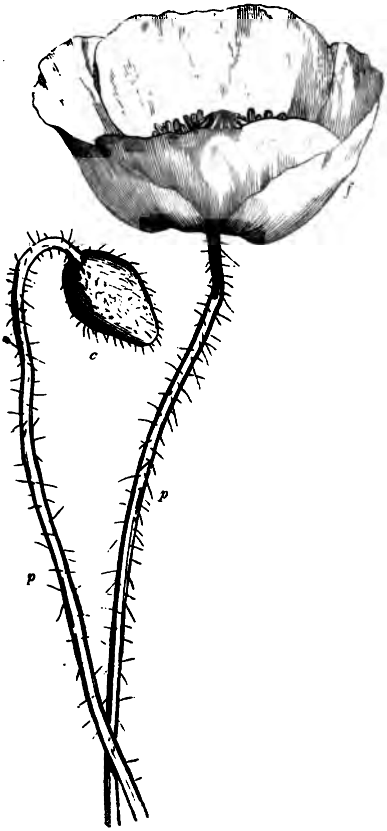


Fig. 358.

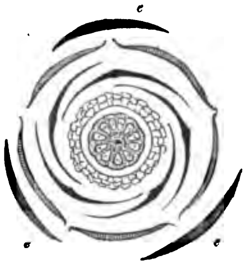


Fig. 356.

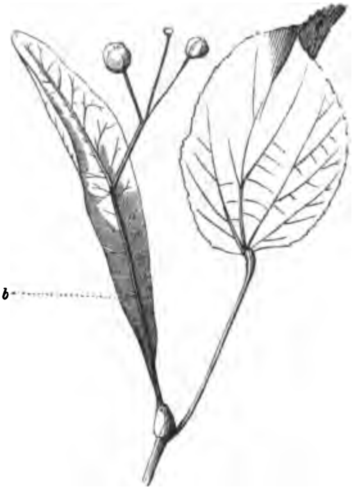


Fig. 357.

Fig. 356. Diagram of the flower of the Mallow, shewing the relation of the different parts of the flower; *e*, *e*, *e*, the three parts of the Epicalyx, within which are five valvate sepals, then five twisted and imbricate petals, then numerous stamens, united by their filaments, and in the centre numerous carpels.

Fig. 357. Leaf and flowering branch of the Lime tree *(Tilia)*. The bract, *b*, is adherent to the peduncle or flower-stalk. The flowers are arranged in a corymbose cyme.

Fig. 358. Flower-stalks of the common red Poppy *(Papaver Rhœas)*, each bearing single flowers (unifloral). Peduncles, *p*, *p*, are covered with spreading hairs; the flower-bud, *c*, is unexpanded, and the calyx is hairy; when the flower expands, the two sepals fall off, and the four petals, *f*, remain, enclosing numerous stamens, and a single pistil.

(Fig. 359), which are either sessile (applied closely to the peduncle) as in the catkin (Fig. 349, p. 149), or are placed on stalks called *pedicels* (Fig. 359). When the peduncle proceeds in a straight line from the base to the apex of the whole inflorescence, it is often called the *Rachis*, or axis of inflorescence (Fig. 335, p. 143). A Peduncle arising from a stem, either subterranean or close to the ground, and bearing a solitary flower, as in the Primrose and Snowflake (Fig. 344, p. 147), in Sowbread (Fig. 360), and in some violets, or bearing numerous stalked (pedicellate) flowers, as in the Cowslip (Fig. 144, *b*, p. 60), Narcissus (Fig. 343, p. 147), or numerous sessile flowers, as in the Daisy and Dandelion (Fig. 361), is called a *Scape* or Radical peduncle. In the female flower of Vallisneria (Fig. 362, *b*), the scape is spiral, and uncoils, so as to allow the flowers to appear above the surface of the water in which the plant grows.

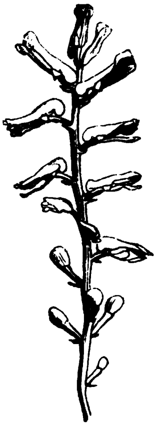


Fig. 359.

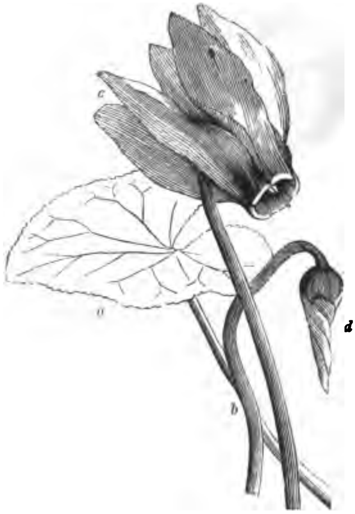


Fig. 360.

210. The Peduncle is usually rounded like a branch, but this is by no means its invariable form. Thus, in various species of Butchers-broom (Fig. 363), and Epiphyllum, it is a broad leaf-like (phylloid) expansion. In the Cashew-nut the pedicels supporting single flowers become succulent, and are used as food. When the peduncle bears numerous flowers, in place of being elongated, it sometimes is shortened

Fig. 359. Peduncle or floral axis of Fumitory *(Fumaria officinalis)*, bearing numerous flowers (multifloral). Each flower is attached to the rachis or floral axis by a short stalk called a pedicel, at the base of which a bractlet is produced. The length of this bractlet, as compared with the pedicel of the fruit, is useful in determining the species of Fumitory.

Fig. 360. Cordate leaf, *a*, and unifloral radical peduncles (scapes) of Sowbread *(Cyclamen europæum)*. The flowering stalks, *b*, arise from a short thickened underground stem. The segments of the corolla in the expanded flower, *c*, are reflexed. In the flower-bud, *d*, the æstivation is contortive (imbricate and twisted).

and thickened, especially at its apex, so as to form a broad flattened disk, as in the Thistle (Fig. 364), Dandelion (Fig. 365), a conical projection, as in the Daisy, a concave surface, as in Dorstenia (Fig. 367), or a hollow fleshy pear-like body, as in the Fig (Fig. 366). The peduncle is transformed, in some instances, into tendrils or spines, at other times its apex is hollowed out, so as to form part of the calyx, as in Eschscholtzia, or of the fruit. Flower-stalks, bearing hairs in place of flowers, occur in the Wig-tree (Fig. 368).

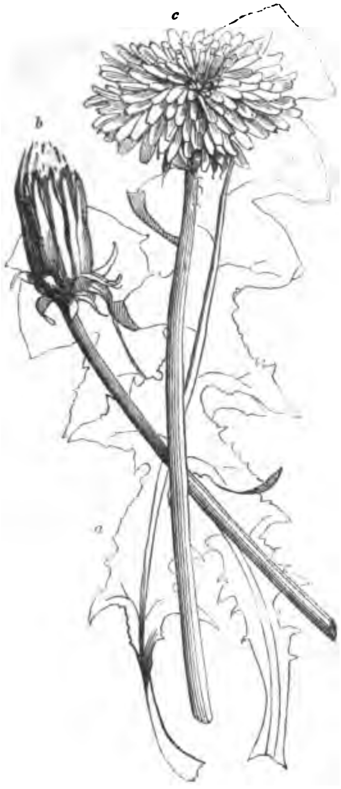


Fig. 361.

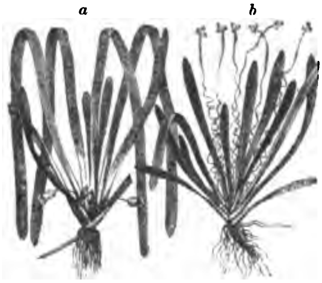


Fig. 362.

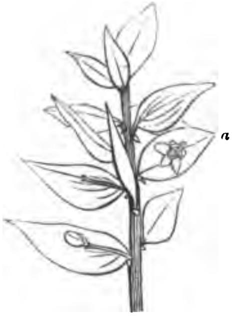


Fig. 363.

Fig. 361. Runcinate leaves, *a*, and radical peduncles or multifloral scapes, *b*, *c*, of Dandelion *(Leontodon Taraxacum)*. In the unexpanded head (capitulum) of flowers, the row of bracts forming the involucre are seen. The expanded head, *c*, consists of numerous flowers, sessile on a flattened receptacle.

Fig. 362. Plants of Vallisneria spiralis; the male plant, *a*, with its flowering stalks spreading outwards. The Female plant, *b*, with its flowers supported on spiral peduncles, which, by their uncoiling, enable the flowers to float on the surface of the water in which the plant grows.

Fig. 363. Branch of Butchers-broom (*Ruscus aculeatus*), bearing male flowers, *a*, on the upper surface of leaves, which must be reckoned leafy (phylloid) pedicels. The flowers are sometimes called epiphyllous, from growing on leaves.

211. The arrangement of the flowers on the peduncle or floral axis, exhibits considerable variety. The simplest kind of inflorescence

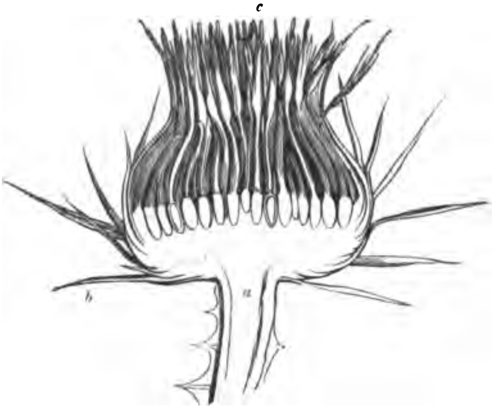
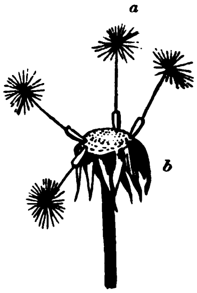


Fig. 364.



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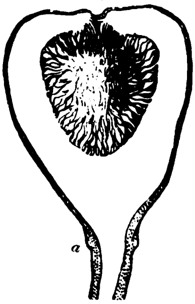

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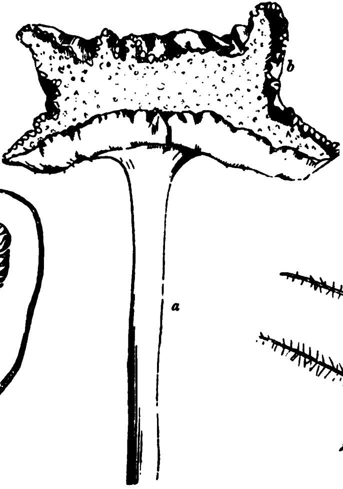


Fig. 367.

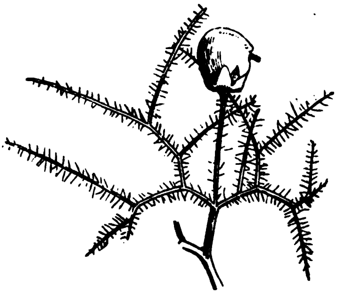


Fig. 368.

Fig. 364. Head (capitulum) of flowers of the Scotch Thistle (*Onopordum Acanthium*), shewing the peduncle, *a*, with the flattened receptacle at the top of it, the involucre, *b*, and the congeries of flowers, *c*.

Fig. 365. Receptacle or flattened apex of the scape of Dandelion (*Leontodon Taraxacum*), in a dry state, throwing off the fruit, *a*, with its stalked hairs (stipitate pappus). The Involucre, *b*, is turned downwards (deflexed), in order to allow the scattering of the fruit, and for the same reason the receptacle becomes slightly convex.

Fig. 366. Peduncle, *a*, of Dorstenia, ending in a multifloral concave receptacle, *b*. The broad receptacle bears numerous flowers.

Fig. 367. Peduncle, *a*, of Fig (*Ficus Carica*), ending in a hollow receptacle, *b*, enclosing numerous male and female flowers.

Fig. 368. Flowering branch of the Wig-tree (*Rhus Cotinus*). Only one of the pedicels bears a flower, the others are abortive, and are covered with hairs.

(floral arrangement) is that in which single flowers are supported on flower-stalks, as is seen in the Gentianella (Fig. 369), and in the common Periwinkle, or in the Pimpernel (Fig. 338, p. 144). In these instances there is a difference in the mode of floral development. In the Gentianella (Fig. 369) the flower, *b*, with two leaves at its base, terminates the general or primary flowering axis, *a ;* in the Periwinkle and Pimpernel (Fig. 338) the floral axis elongates, producing leaves, while the flowers, *b*, are borne on secondary axes or stalks, which are axillary and lateral. In the former cases the axis is arrested in its growth, and the inflorescence is *Definite* or *Determinate ;* in the latter the axis is progressive, and the inflorescence is *Indefinite* or *Indeterminate.* These plants illustrate, in their simplest forms, two marked forms of Inflorescence, which it is necessary to bring more fully under notice.

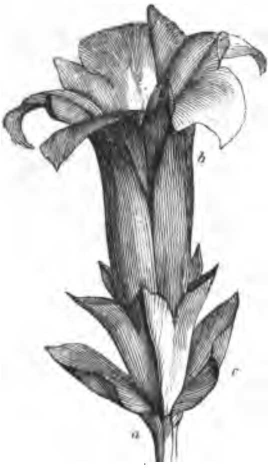


Fig. 369.

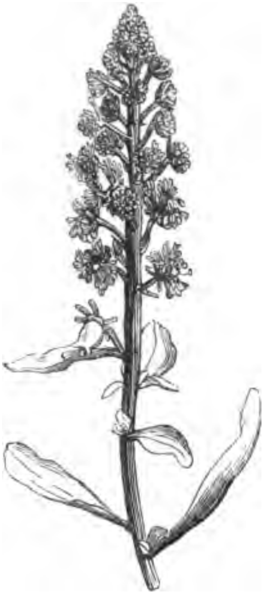


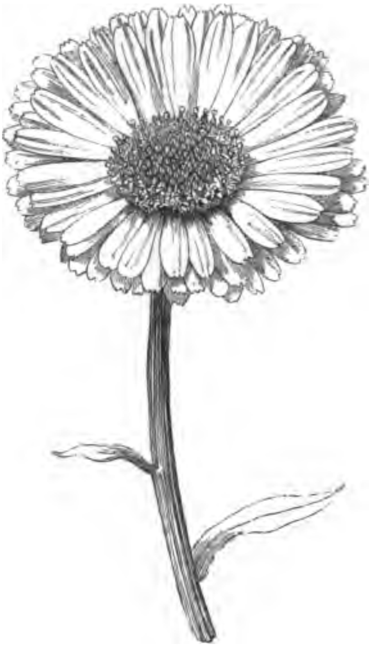
Fig. 370.

212. *Indeterminate or Indefinite Inflorescence.*—The simplest form of this inflorescence is that in which the flowers arise singly from the

Fig. 369. Flowering stem of Gentianella (*Gentiana acaulis*). The plant produces a single flower, and it is called unifloral. The termination of the axis, *a*, bears two leaves or bracts, *c*. The flower, *b*, with its calyx and corolla, terminates the axis. This is the simplest form of definite inflorescence. If other axes are produced in such a case, they arise from the axil of the bracts, *c*, and the flowers expand after the central one, *b*, or in what is called a centrifugal manner. Each axis ends in a solitary flower.

Fig. 370. Simple Raceme of Mignonette (*Reseda odorata*). The flowers arise singly from the axil of bractlets, and they expand in a centripetal manner, the lowest opening first. Each flower is supported on a pedicel, by which it is connected with the peduncle or rachis.

axil of ordinary leaves, which, in this instance, serve the purpose of bracts, while the axis goes on elongating and bearing leaves at its apex (Fig. 338, p. 144). In place of a single flower, however, there are frequently several flowers produced on a floral axis in this kind of inflorescence, as is seen in some species of Speedwell (Fig. 340, p. 145), in which there arises from the axil of a bract a cluster of flowers expanding in an ascending series from below upwards. As the flowers in the indefinite inflorescence are produced as buds in the axils of leaves, they are denominated *axillary;* and, when numerous, they follow the ordinary law of leaf development—the lowest (*i. e.*, those next the primary axis), expanding first when the floral axis is elongated (Fig. 338, p. 144, and Fig. 340, p. 145), or the outermost when the axis is depressed or abbreviated (Fig. 318, p. 136, and Fig. 371). The expansion of the flowers, in such cases, is denominated *centripetal* in consequence of proceeding in a progressive manner towards the centre or apex.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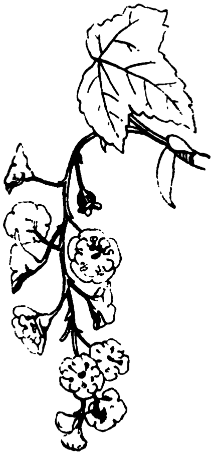
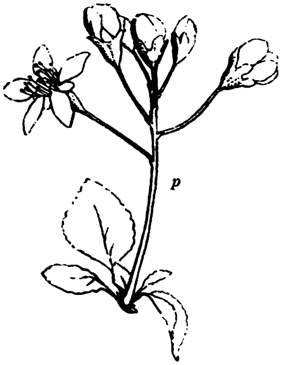


Fig. 372.

Fig. 371. Head (Capitulum) of the Common garden Marygold (*Calendula officinalis*). The flowers have no pedicels, and are arranged in numerous rows on a flattened peduncle (receptacle). The expansion of the flowers is centripetal, *i. e.*, from without inwards.

Fig. 372. Simple Raceme of Currant (*Ribes rubrum*). A multifloral peduncle arises from a bract, and bears pedicellate flowers. The pedicels (partial flower-stalks) are nearly equal in length, and each arises from a bractlet. The flowers nearest the stem of the plant expand first, hence the order is centripetal.

213. Axillary flowers, on elongated and shortened axes, present different forms of inflorescence, according as the flowers are stalked or sessile, the stalks simple or branched, and equal or unequal in length.



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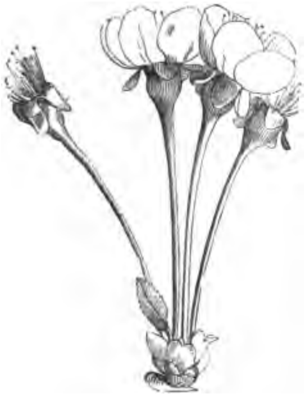

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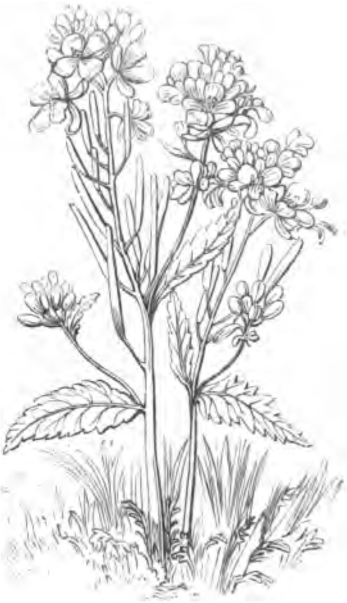


Fig. 374.

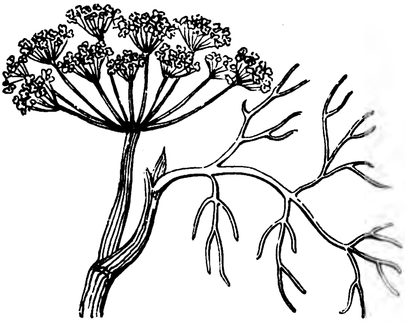
When the primary floral axis (peduncle or rachis) lengthens and bears equally stalked (pedicellate) flowers, each originating from a bractlet,

Fig. 373. Simple indefinite corymb of a kind of Cherry (*Cerasus Mahaleb*). A multifloral peduncle, *p*, arises from a bract, and bears pedicellate flowers, the lower pedicels being longer than the upper, so that the flowers form nearly a flat surface above. The lowest flowers expand first, and hence the order is centripetal.

Fig. 374. Inflorescence of a cruciferous plant, a kind of mustard (*Sinapis orientalis*). In the young state the flowers are corymbose, while in the advanced state they become racemose. The fruit-pods (*Siliquæ*) are supported on nearly equal pedicels, while the lowest flowers, in their partially expanded state, have the longest pedicels, and thus form a corymb. The plant shows the transition from a corymb to a raceme. It is said to be the *Charul* of the Bible, translated nettles in the authorised version (Job. xxx. 7; Prov. xxiv. 30, 31; Zeph. ii. 9).

Fig. 375. Simple umbel of the Cherry (*Prunus Cerasus*). The flowers are pedicellate, and arise from a common point, surrounded by bracts, the pedicels being nearly equal. The flowers expand centripetally.

a *raceme* is produced, as in the Hyacinth, Barberry, Currant (Fig. 372), Mignonette (Fig. 370), and Fumitory (Fig. 359, p. 152). In this instance, the lowest flowers, *i. e.*, those next the primary axis, are first expanded, and the others follow in succession from base to apex. When the raceme has the lower flowers supported on longer stalks than the upper, in such a way that all form nearly a level top, as in the Hawthorn, and some species of Cerasus (Fig. 373), a *corymb* is formed. In Cruciferous plants (Fig. 374), the flowers, when first produced, frequently appear as a corymb, and when the floral axis elongates, they form a raceme. If the primary axis of a raceme is shortened, so that the floral stalks all proceed from apparently the



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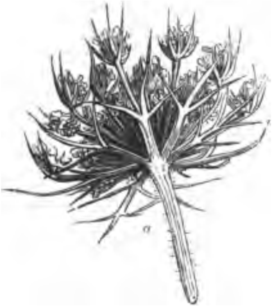


Fig. 377.

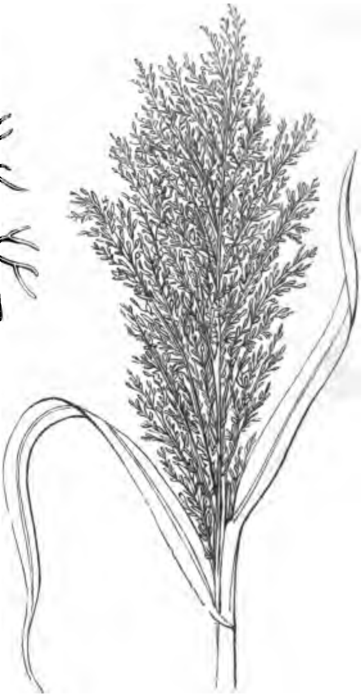


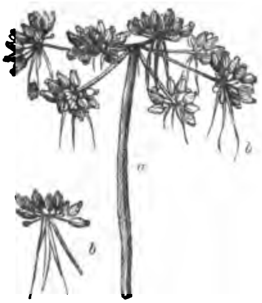
Fig. 378.

Fig. 376. Compound umbel of Common Dill (*Anethum graveolens*), having both primary and secondary umbels, without either involucre or involucel. The petiole of the leaf is large and sheathing, and has been denominated pericladium. The plant is the *Anethon* of the New Testament, translated Anise in Matth. xxiii. 23.

Fig. 377. Compound umbel of the Carrot (*Daucus Carota*), with a general involucre (verticillate bracts), *a*, and partial involucres (involucella), *b*.

Fig. 378. Panicle, or loose branching raceme of a kind of Reed (*Arundo Donax*). The flowers are arranged in small spikelets, which are supported on a branching peduncle. The plant is supposed to be the *Kaneh* of the Bible translated Reed (1 Kings xiv. 15; 2 Kings xviii. 21; Job xl. 21; Is. xix. 6; xxxv. 7; xxxvi. 6; xlii. 3; Ezek. xxix. 6).

same point, forming nearly equal *radii*, as in Crow-garlic, Cowslip, Auricula, and Cherry (Fig. 375), an *umbel* is produced. In the inde-



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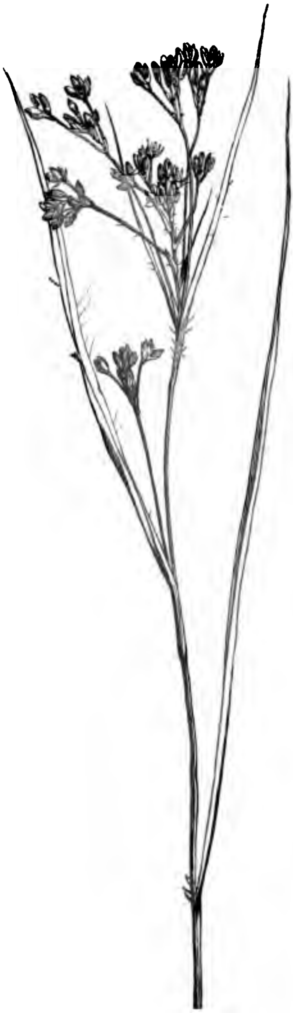

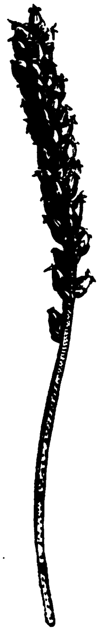

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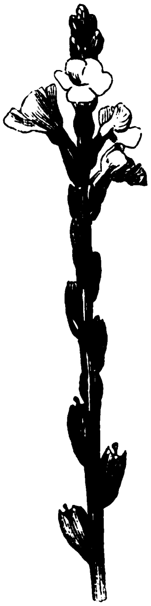


Fig. 382.

Fig. 380.

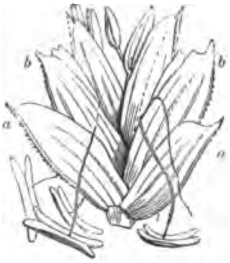
Fig. 379. Compound umbel of Fool's-parsley (*Æthusa Cynapium*). The peduncle, *a*, bears a general umbel without an involucre, while the radii bear umbellules, *b*, *b*, with an involucellum composed of reflexed pendulous bracts.

Fig. 380. Panicled Inflorescence of a Rush (*Luzula nivea*), presenting the characters both of a raceme and a corymb.

Fig. 381. Spike of Rib-grass (*Plantago*) consisting of a rachis (general peduncle), bearing sessile flowers, which expand centripetally from below upwards.

Fig. 382. Spike of Vervain (*Verbena*), consisting of sessile flowers arranged alternately on a common floral axis, and with a centripetal order of expansion.

finite umbel, the outermost flowers, *i. e.*, those of the circumference, expand first. The simple Raceme, Corymb, and Umbel, may become compound by the stalks of the flowers branching. Thus, in the Horse-chestnut (Fig. 335, p. 143), there is a compound raceme. In the case of the umbel, the branching takes place by the secondary stalks coming off from a point like radii of a circle, in the same way as the primary



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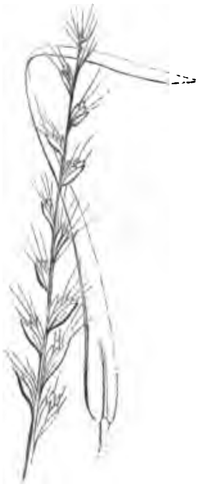

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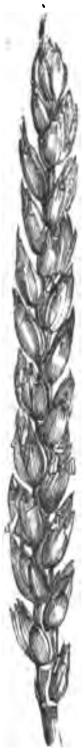

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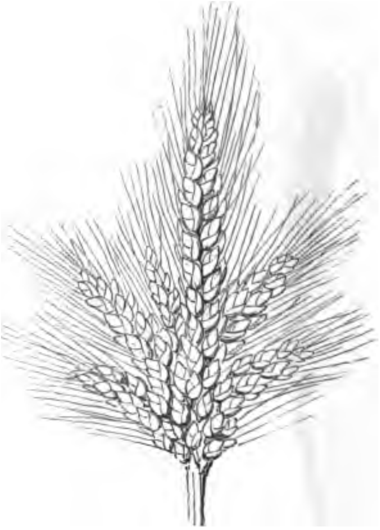

Fig. 386.

Fig. 383. Spikelet of Wheat (*Triticum*), composed of a number of sessile flowers, *b*, *b*, enclosed within two bracts (glumes), *a*, *a*. The stamens hang by long thread-like filaments, and the anthers are versatile.

Fig. 384. Compound Spike of Wheat (*Triticum*), formed by numerous spikelets (Fig. 383), arranged alternately on a common rachis, which has a zig-zag form.

Fig. 385. Compound Spike of Darnel-grass (*Lolium temulentum*), shewing awned (aristate) spikelets, arranged alternately on a common rachis. The plant is supposed to be the *Zizanion* of the New Testament, and translated *tares* (Matth. xiii. 25, &c.), the *infelix Lolium* of Virg. Georg. i. 154.

Fig. 386. Branching compound Spike of Egyptian Wheat (*Triticum compositum*). Several compound spikes come off from the rachis, so as to form a sort of cluster. The wheat is awned. It appears to be the *Chittah*, or wheat of Scripture, which is mentioned in some places as bearing several ears on one stalk (Gen. xxx. 14; Exod. ix. 32, xxix. 2, xxxiv. 22; Deut. viii. 8; xxxii. 14, &c. &c.)

ones did (Fig. 376). The bractlets at the base of the primary stalks, or, in other words, at the base of the primary umbel (Fig. 377, *a*, and Fig. 347, *a*, p. 148), are arranged in a whorled manner, and form an involucre, and such is also the case with the bractlets at the base of the secondary flower-stalk or secondary umbel (Fig. 377, *b*, and Fig. 347, p. 148). The secondary, or partial umbels, are called *Umbellules*, and the verticillate bractlets receive the name of *Involucel*. In some instances, as in Fool's-parsley (Fig. 379), there is no general involucre, but simply an involucel (Fig. 379, *b b*, p. 159); while, in other cases, as in Fennel, neither involucre nor involucel are developed. Compound umbels are frequent in umbelliferous plants, such as Hemlock, Carrot, and Parsley.

214. In compound inflorescences, there occurs a combination of these forms. Thus, the primary divisions may be racemose, or corymbose, or umbellate, while the secondary are of a different nature. A

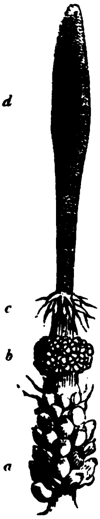

Fig. 387.

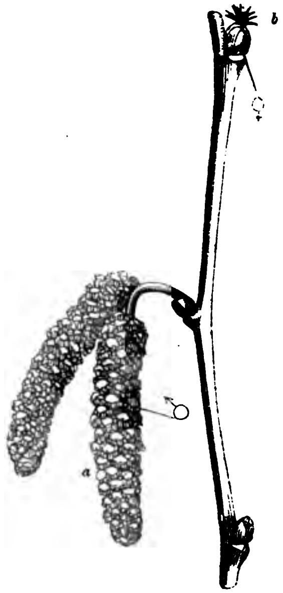

Fig. 388.

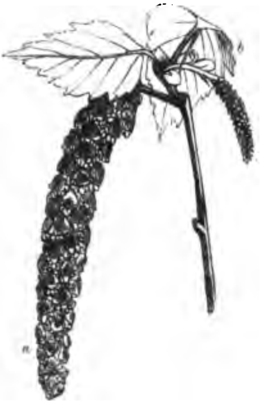

Fig. 389.

Fig. 387. Spadix of Cuckow-pint (*Arum maculatum*), consisting of numerous male flowers, *b*, female, *a*, and abortive flowers, *c*, sessile on a succulent rachis, and enclosed in a spathe, which in the figure has been removed. The rachis ends in a succulent club-shaped mass of cellular tissue, *d*.

Fig. 388. Flowering branch of Hazel (*Corylus Avellana*), bearing male flowers, *a*, and female flowers, *b*. The former are in catkins (amenta), composed of numerous flowers arising from scaly bracts arranged on a common rachis, and all falling off at once; the latter consist of several flowers covered with bracts, sessile on a common rachis, and producing nuts. The tree is said to be amentiferous (catkin-bearing).

Fig. 389. Flowering branch of Birch (*Betula alba*), bearing male and female amenta. The male catkin, *a*, is composed of sessile flowers, with scaly bracts, and such is also the case with the female catkin, *b*. The tree is also amentiferous.

raceme in which the secondary branch assumes the form of a corymb, or a corymb in which the secondary branches are racemose, is called a *Panicle*, a form of inflorescence met with in many grasses (Fig. 378), and in some rushes (Fig. 380). This term, however, is rather vaguely applied, and includes often definite, as well as indefinite, forms of inflorescence. It is usually applied to any loose racemose inflorescence in which the stalks are irregularly elongated and branched. When the panicle is shortened, as regards its secondary branches, and forms a compact cluster resembling a bunch of grapes, as in Lilac and Horse-chestnut (Fig. 335, p. 143), it is called a *Thyrsus*.

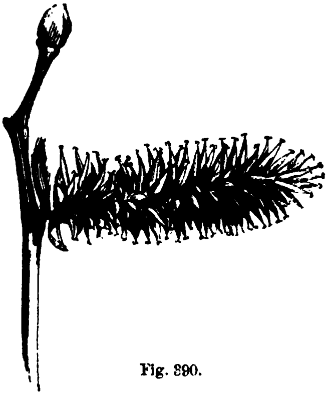

Fig. 390.

215. In the instances of inflorescence which we have noticed, the flowers are all supported on stalks either of the same or different lengths. When the flowers are sessile, *i. e.*, without stalks, different forms of the indefinite inflorescence arise. A raceme, with sessile flowers, becomes a *Spike*, as in Plantago (Fig. 381), and Vervain (Fig. 382). In grasses the flowers are arranged in small spikes called Spikelets (locustæ), as seen in Figure 383, and these spikelets are themselves arranged either in a panicled form, as in Oats, or in a spiked form, as in Wheat (Fig. 384), and Darnel grass (Fig. 385). The latter may be called a compound spike, consisting of a series of small spikes sessile on a common rachis. Occasionally, as in Egyptian wheat (Fig. 386), several compound spikes proceed from the top of the stalk or culm. A *Spadix* is a succulent spike, enclosed in a sheathing bract called a Spathe, as in the Cuckow-pint (Fig. 342, p. 146, and Fig. 387), and Æthiopian Calla, where it is simple, and in Palms (Fig. 341, p. 146), where it is branching and compound. A *Catkin*, or *Ament*, is a spike having scaly bracts. It occurs in the Willow (Fig. 348, p. 148), in the Walnut (Fig. 349, p. 149), in the Hazel (Fig. 388, *a*), the Birch (Fig. 389, *a*) the Poplar (Fig. 313, p. 134), and in many trees which are hence called *Amentiferous*. Catkins bearing sterile flowers only (Fig. 388, *a*) generally fall off early, and in one piece. Some restrict the term catkin to such deciduous forms of inflorescence; while others include also the fertile scaly spikes of Hazel (Fig. 388, *b*), of Birch (Fig. 389, *b*), and of Willow (Fig. 390). The catkin is sometimes branching, *i. e.*, produces numerous separate catkins on a common axis, as in the male flowers of the Fir. The *Cone* (Fig. 353, p. 150) of the Pine, Spruce, Fir, and other cone-bearing plants, is a female spike of flowers with hard scales, while the *Strobilus*

Fig. 390. Female spike or catkin of another amentiferous tree, the Willow (*Salix*). The flowers are nearly sessile, and are arranged along a common rachis.

(Fig. 352, p. 149) of the Hop is a similar kind of spike with membranous scales. Some of these modes of inflorescence determine the nature of the fruit, and will be noticed again when describing it.

216. In the Spike, the Spadix, and the Catkin, the floral axis is elongated. Other cases occur in which sessile flowers are produced on a shortened axis. The *Head* (capitulum) is a congeries of sessile flowers, supported on a more or less flattened axis (receptacle), and expanding centripetally. In the American Button-bush the heads are globular, in some species of Teazel, elliptical, while in Scabious (Fig. 391), and in composite plants, as Sunflower, Dandelion (Fig. 361, p.

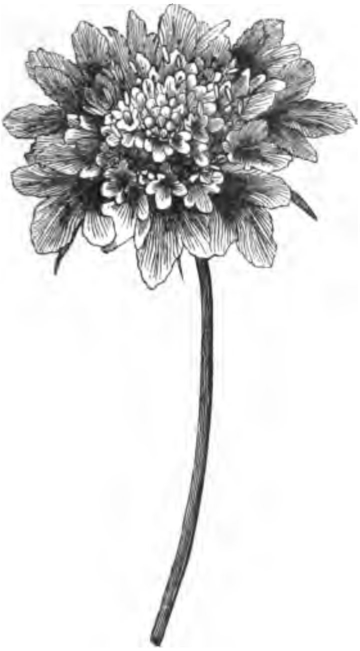

Fig. 391.

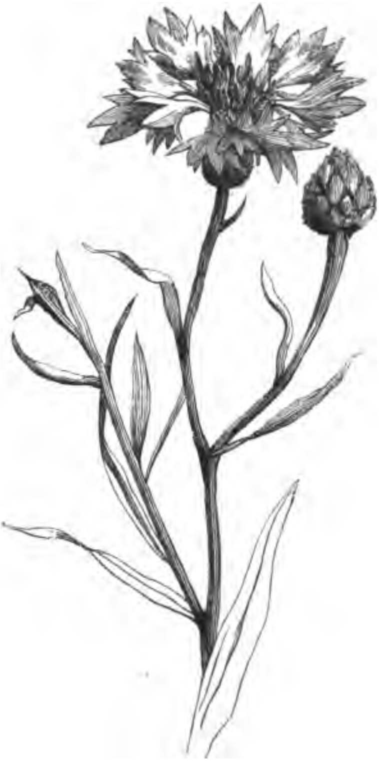

Fig. 392.

Fig. 391. Head (capitulum) of Scabious (*Scabiosa*) consisting of numerous sessile, or nearly sessile flowers, arranged on a common flattened receptacle, and expanding centripetally, *i. e.*, from the circumference towards the centre. The flowers are surrounded by a series of bracts, which form an involucre.

Fig. 392. Heads (Capitula) of Corn Bluebottle (*Centaurea Cyanus*). One of the heads has the flowers expanded, the other contains the flowers in bud. Each head consists of numerous sessile flowers on a flattened receptacle, surrounded by involucrate bracts, called phyllaries, and expanding centripetally. The separate heads are produced in a centrifugal manner, and form a sort of corymb. This is an instance of mixed inflorescence, in which the general inflorescence is centrifugal, and the partial inflorescence centripetal.

153), Thistle (Fig. 364, p. 154), Centaury (Fig. 392), and Marygold (Fig. 371, p. 156), they are somewhat hemispherical, with a flattened, slightly hollowed, or convex disk. In the latter class of plants, besides the general bracteal envelope (Fig. 346, *i*, p. 148), called the involucre, there are frequently *chaffy* and *setose* bracts at the base of each flower.* In Dorstenia (Fig. 367, p. 154), the receptacle of the flowers varies from a flattened disk to one in which the edges are incurved and turned upwards. When this incurvation of the receptacle is complete, so as to form a hollow cavity bearing the flowers inside, the inflorescence is like that of the Fig (Fig. 366, p. 154). By this

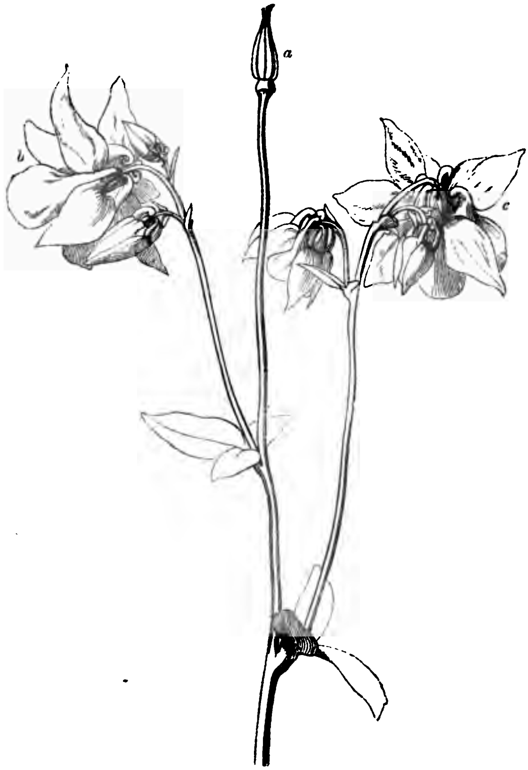

Fig. 393.

Fig. 393. Flowering stem of Columbine *(Aquilegia vulgaris)*. The Inflorescence is a corymbose cyme, or a definite corymb. The axes bear solitary flowers, and are developed in a centrifugal manner. The central flower, *a*, was first expanded, terminating the primary axis; then the secondary axis was produced, bearing a solitary flower, *b*; then the tertiary unifloral axis, *c*, and so on. The axis, *a*, has passed into fruit.

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* Occasionally the bracts of the Capitulum produce pedicels bearing small capitula. In this way there is a resemblance to the umbel. Dr. Murchison noticed a peculiar umbellate form of inflorescence occurring in the Dandelion, where each stalk arising from a common point bore on its extremity tubular florets. In the Hen-and-Chicken Daisy there is a similar tendency to form umbellate capitula.

mode of formation the flowers at the circumference are turned towards the apex, while the real centre remains next to the stem of the plant.

217. *Determinate or Definite Inflorescence.*—In this inflorescence, the flowers, in place of arising from axillary buds, are considered as represented by terminal buds, beyond which the axis does not extend. The simplest form is that in which a single floral axis is produced, terminated by a solitary flower, as in Gentianella (Fig. 369, p. 155), with two opposite leaves, *c*, at the base of the inflorescence. When such an inflorescence branches, it is by the production of axillary buds, whence arise floral axes, terminated, as the first axis, by solitary flowers. The axes are thus arrested in their development, and do not grow in an indeterminate manner. This kind of inflorescence is very commonly associated with opposite leaves, but it occurs also in plants with alternate leaves (Fig. 393).

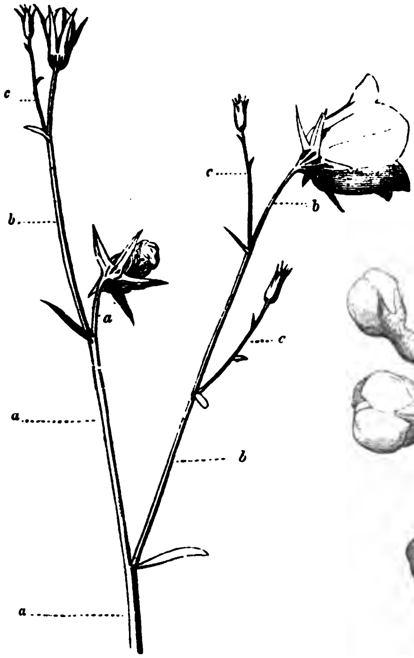


Fig. 394.

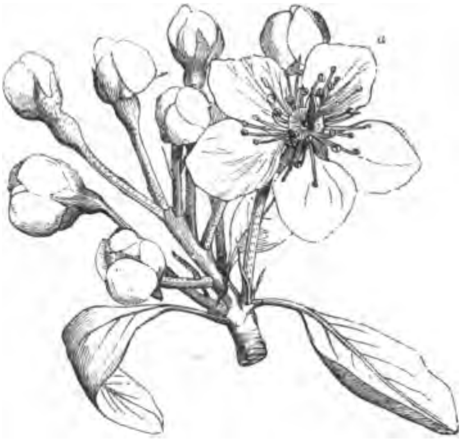


Fig. 395.

218. If such a plant as Gentianella, with opposite leaves, produces

Fig. 394. Racemose cyme, or definite raceme of Rampion (*Campanula Rapunculus*). The primary axis, *a a a*, ends in a flower which was the first expanded. From bracts on this axis arise secondary axes, *b b b*, each ending in a solitary flower. These axes gave off tertiary axes, *c c c*, also unifloral. The order of expansion centrifugal.

Fig. 395. Definite corymb or corymbose cyme of the Pear tree (*Pyrus communis*). The flower, *a*, is first expanded, and terminates the primary axis. The other axes expand their flowers in succession in a centrifugal manner.

additional flowers, it does so in a descending series, that is to say, the buds produced by each of the opposite leaves on the stem (Fig. 369, *c*, p. 155), and bearing solitary flowers, expand after the flower terminating the primary axis, and successively later as we proceed downwards. Thus, the expansion of the flowers is *centrifugal*, *i.e.*, farther and farther from the central terminal bud of the primary axis, and later as regards time. A racemose or spiked inflorescence of this kind would be at once distinguished by the upper flowers being first expanded, and not the lower, as in the indefinite raceme and spike. Thus, in Figure 393, we have an example of a definite raceme (nearly a corymb), in which the separate floral axes end in solitary flowers, and the upper ones are first expanded. The flower at *a* ends the primary axis, and it has passed into fruit, the flower at *b* succeeded it, then that at *c*, and so on—the expansion of the flowers being the reverse of what is seen in the indefinite raceme or corymb. The flower terminating the primary axis has sometimes a shorter stalk than those arising subsequently, and in such cases there may be a difficulty in distinguishing between the definite and indefinite forms. In Figure 394, the inflorescence of Rampion is given, in which *a a a* is the primary floral axis, ending in a solitary flower, which has passed into fruit, *b b b* are secondary floral axes, arising from bracts below the first flower, and ending in single flowers, which are expanded more or less completely; while *c c c* are tertiary floral axes, ending in flower-buds unexpanded. The order in which the flowers expand determines the nature of the inflorescence. Attention must be paid to the axis terminating in a single flower, the bract which it gives off laterally, and the flower-bud produced between the bract and the axis. In Figure

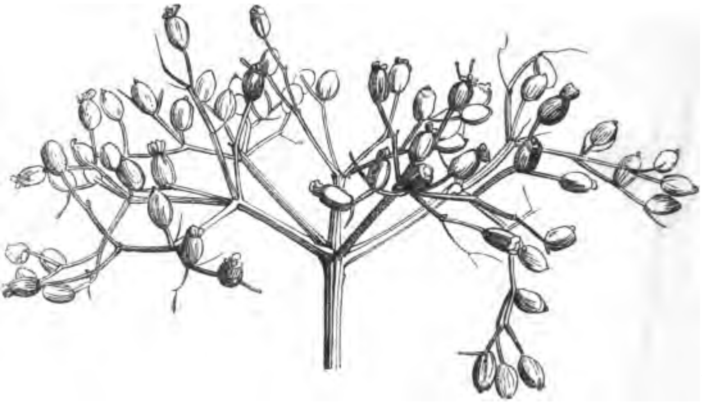


Fig. 396.

Fig. 396. Umbellate and racemose cyme of Elder (*Sambucus nigra*). The different unifloral axes seem to arise from one point, and then subdivide. The inflorescence consists of a series of unifloral axes, aggregated together, producing flowers in a centrifugal manner. The mode of floral expansion distinguishes this from the umbellate, corymbose, and racemose forms of Indefinite Inflorescence.

395 is shewn the definite corymb of the pear tree, in which the solitary flower, *a*, ends the primary axis, and is first developed, the other unifloral axes being subsequently formed, and their flowers expanding centrifugally.

219. When the different floral axes in the definite inflorescence come off close to each other, and are much shortened, there is often apparent confusion in the arrangement, and it is only by noticing the development of the flowers in the different clusters that we can pronounce on the nature of the inflorescence. The branched kind of definite inflorescence is seen in the *Cyme.* This is a corymbose inflorescence, more or less branched, forming a cluster of flowers, which is either flattened at the top, or has a rounded contour. It is illustrated in the Elder (Fig. 396), the Hydrangea, and the Laurustinus. It appears like a combination of the umbel and corymb, but is known by its centrifugal floral expansion.

220. The mode in which the cyme is formed may be studied in the common spearwort, and other species of chickweed. In them, as shewn in Figure 397, there is a solitary flower, *a*, which terminates the primary axis, and has two opposite leaves, *b*, at its base. Each of these leaves (bracts) gives origin to flower-buds, which form axes, *c c*, ending in solitary flowers. Each of these secondary axes, in their turn bear opposite bracts, or leaflets capable in the same way of forming tertiary axes, with solitary flowers, and so on until the plant is exhausted, or the axes produced have no leaf-nodes. This division, by pairs of axes, forms a spreading, loose, *dichotomous* (dividing by pairs) cyme. If three whorled leaves develope axes the cyme becomes *trichotomous* (dividing by threes). Sometimes the two bracts on the axis do not produce flower-buds, and then the primary axis, with its single flower, is alone present, with two empty bracts on the stalk, as seen in the Hearts-ease (Fig. 398, *b*) which produces a unifloral cyme. At other times the primary axis produces a solitary flower, and only one of the bracts developes a flower-bud, as in the common Bind-weed (Fig. 399), in which we meet with a bifloral cyme, *a*, and also unifloral cymes, as at *b b*.

221. If the flower-buds on one side of a dichotomous cyme are the only ones developed, it becomes *unilateral*, and often turns round in a peculiar way, so as to resemble a snail, or the tail of a scorpion, and hence it is denominated *helicoid* or *scorpioid.* The terms gyrate and circinate are also sometimes applied. The same thing occurs also in alternate-leaved plants, where each leaf or bract produces one flower, and a flower-bud which elongates into an axis between the first flower and the bract. In such cases the flowers seem to be placed opposite the leaves, and when the leaves disappear, or are abortive, as in many of the Borage tribe (Fig. 400), it is difficult to determine whether the inflorescence is a one-sided (unilateral) raceme, or a series of single-flowered axes, produced in a racemose manner. The appearance of the helicoid cyme is represented in Figure 400, in the case of the

Forget-me-not; on the axis a leaf, *c*, gives origin to a flower-stalk, ending in a solitary flower, *a;* there are no bracts developed on this primary floral axis, but two racemose cymes, *b b*, are given off, each

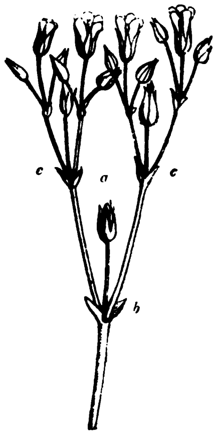
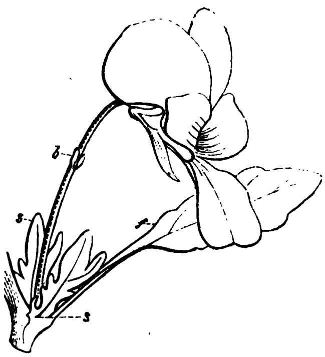


Fig. 397.



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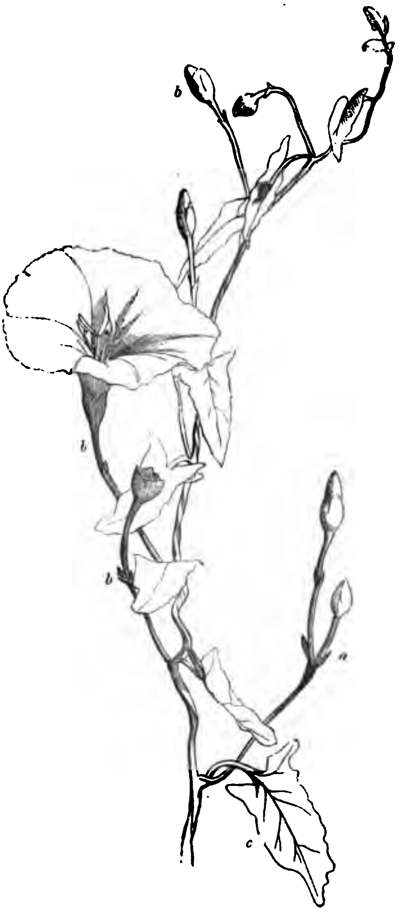


Fig. 399.

Fig. 397. Dichotomous cyme of Mouse-ear Chickweed (*Cerastium*). The primary floral axis ends in a solitary flower, *a*, which expands first. The axis bears two bracts, *b*, each of which gives origin to secondary axes, each ending in a solitary flower, and bearing two bracts, *c c*, which in their turn give rise to unifloral tertiary bract-bearing axes, and so on. When three bracts are produced, and three axes, the cyme becomes Trichotomous. When the axes are much shortened, and the flowers are brought nearer to each other, the formation of the cyme is rendered obscure.

Fig. 398. Unifloral cyme of the Pansy (*Viola tricolor*). The primary axis bears a single flower, and below it are two bracts, *b*, indicating the points where secondary axes would appear if present. The bracts are empty. *f*, the leaf; *s s*, stipules.

Fig. 399. Bifloral, *a*, and unifloral, *b b b*, cymes of Convolvulus. The axis, *a*, arising from a leaf, *c*, ends in a solitary flower, and produces two bracts, one of which gives origin to a secondary floral axis. The axes, *b b b*, produce solitary flowers with empty bracts.

of which curls up in a circinate manner. These cymes are formed by a series of single-flowered axes, which are produced in a secund manner, *i.e.*, only on one side. The theoretical formation of this inflorescence is given in Figure 401, where the primary floral axis, 1, ends in a solitary flower, and so do the other axes from 2 to 10. The small dotted lines indicate the points where floral leaves (bracts) occur. The expansion of the flowers is centrifugal. The flower of axis 1 expands first; this axis gives origin to a flower-bud forming axis 2; in its turn axis 2 expands its solitary flower, and gives rise to axis 3, and so on. Thus, the inflorescence is composed of a series of unifloral axes produced from each other, and not alternating to right and left, but always developed on one side, forming a broken line, which has a

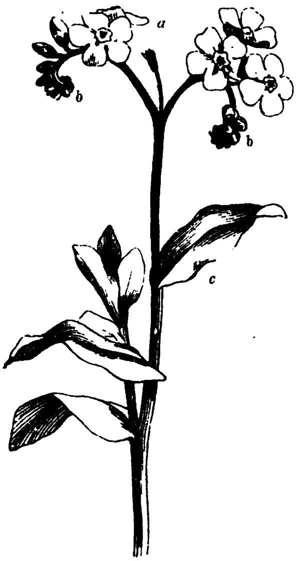


Fig. 400.

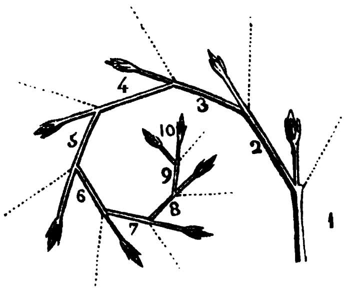


Fig. 401.

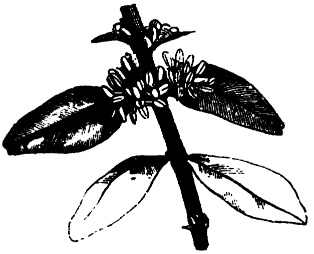


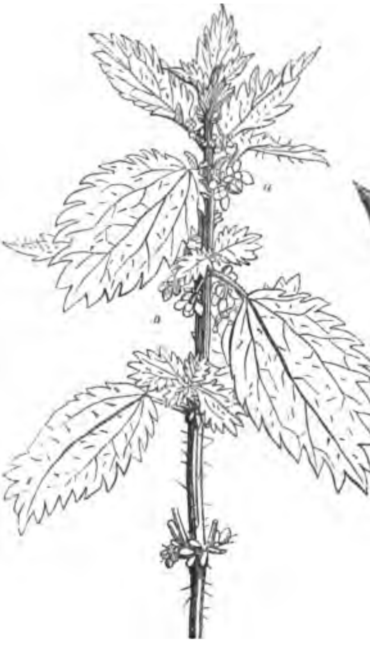
Fig. 402.

Fig. 400. Helicoid cymes of Forget-me-not (*Myosotis palustris*). The floral axis arises from a leaf, *c*, and ends in a solitary flower, *a*. From this axis proceed in a dichotomous manner helicoid or scorpioid cymes, *b b*. Each flower is the termination of a separate axis, developed on one side only (unilateral or secund), and the whole inflorescence is curved like the shell of a snail, or the tail of a scorpion. The inflorescence is ebracteated, *i.e.*, the bracts are suppressed.

Fig. 401. Diagram to illustrate the formation of a scorpioid cyme. The first axis, 1, ends in a solitary flower. On one side of this axis a node is produced, which gives rise to the secondary axis, 2, bearing a solitary flower, which is developed after 1. This axis in its turn produces a floral node, giving rise to a tertiary unifloral axis, 3, and so on, up to 10. At the same time the inflorescence becomes curved, as the development of the axes takes place on one side. The non-developed nodes are marked by dotted lines opposite the points whence the floral axes arise.

Fig. 402. Clustered flowers of the Box (*Buxus sempervirens*). Each cluster is produced in the axil of one of the opposite entire leaves. The flowers expand centrifugally and form a glomerulus.

tendency to return upon itself. In the Diagram ten unifloral axes are shewn, each bearing a solitary flower. When the bracts are abortive, as in the Borage tribe, the nature of the inflorescence is not detected at first sight. The formation of the different axes between the previously expanded flower and the bract, indicates the nature of the inflorescence. When the internodes of such a floral axis are shortened, and the bracts disappear, some anomalous inflorescences are produced, as in Solanaceæ. The appearance of a peduncle opposite a leaf leads often to a correct conclusion in regard to the morphology of the inflorescence; in the same way as has been already noticed, in the case of the tendrils of the Vine (¶ 95), which are leaf-buds producing separate axes, in a centrifugal manner.



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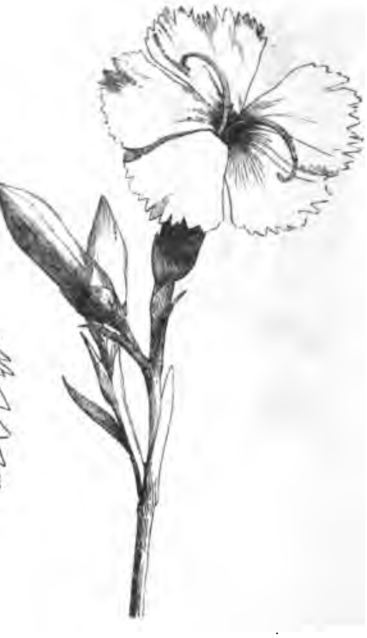


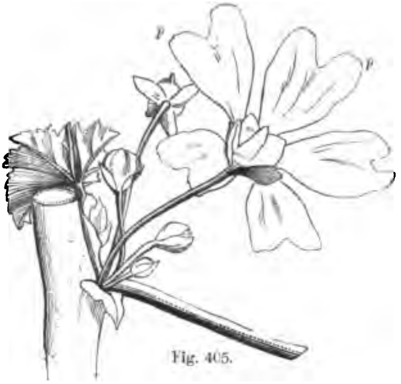
Fig. 404.

222. In some kinds of cymose inflorescence the flowers are sessile on an elongated axis, forming a cymose spike; in other instances they are nearly sessile, and form a rounded head or short spike, called a *Glomerulus*, as seen in species of nettle (Fig. 403), and in the

Fig. 403. Flowering stalk of Nettle (*Urtica urens*), with clustered definite inflorescence, *a a*, called a glomerulus. The leaves are serrated, and covered with stinging hairs.

Fig. 404. Flowering stalk of Clove-pink (*Dianthus Caryophyllus*). The flowers form a fascicle The inflorescence is definite and centrifugal. The plant is the origin of all the varieties of Carnation.

Box (Fig. 402). Sometimes stalked flowers arise from the same part of the axis, in the form of a cluster, called a *Fascicle*, as in the Mallow (Fig. 405), and in species of Pink (Fig. 404). In the case of Labiate plants, as Mint (Fig. 407), and Dead-nettle (Fig. 339, p. 145), the flowers appear to be in whorls, but in reality they arise in two clusters or fascicles, called *Verticillasters*, which are cymes bearing a few nearly sessile flowers, expanding centrifugally. Each cluster is produced from one of the opposite leaves. Truly whorled flowers are seen in the Common Mare's tail (Hippuris vulgaris), in which each leaf of the whorl produces a single flower.



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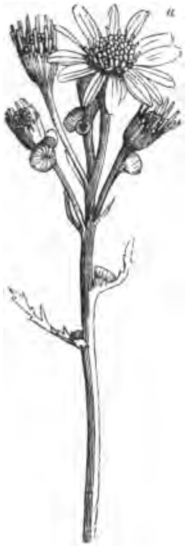

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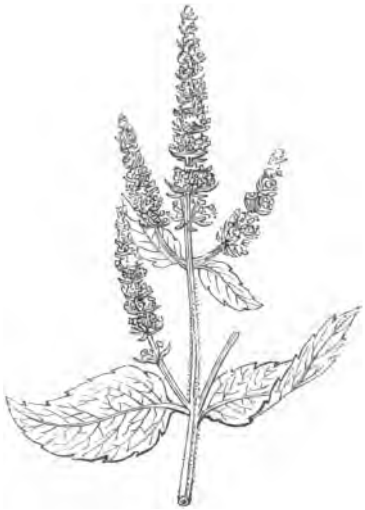

Fig. 407.

Fig. 405. Fascicle of Mallow (*Malva sylvestris*). The inflorescence is definite, with centrifugal expansion. The flowers come off from the same point, and are supported on stalks. The stem is prolonged beyond the flowers, so that the general development is indefinite, while the clusters of flowers are definite. The petals of the flower, *p*, are obcordate, and the calyx is double.

Fig. 406. Flowering stalk of a kind of Groundsel (*Senecio*). The flowers are in heads (capitula), and open from the circumference inwards in an indefinite centripetal manner. The heads of flowers, on the other hand, taken collectively, expand centrifugally—the central one, *a*, first. Each head of flowers terminates a separate axis. They form together a definite corymb. The inflorescence is called mixed.

Fig. 407. Flowering stalk of Mint (*Mentha sylvestris*). The flowers, taken collectively, have a spiked appearance. The separate verticillasters (clusters) are produced in the axils of small leaves, and the flowers forming them are developed centrifugally; while the clusters, taken as a whole, are developed centripetally from below upwards. It is a mixed inflorescence, and exhibits what has been called a Definite Spike. The plant is probably the *Heduosmon* of the Greeks, mentioned in Matth. xxiii. 23, and in Luke xi. 42.

223. *Mixed Inflorescence.*—There are certain kinds of inflorescence in which there is a combination of the definite and indefinite forms. These have been called *Mixed.* They are by no means uncommon in the Vegetable Kingdom, and they require to be studied carefully. In Composite plants, the branches bearing the heads of flowers (capitula) are often developed centrifugally, while in the individual heads the expansion is centripetal. The general inflorescence, in such a case, may be said to be definite, while the partial inflorescence is indefinite. Thus, in Figure 406, the central head of flowers is expanded, while the others are only partially so; the inflorescence is mixed, and the whole puts on the aspect of a corymbose cyme, with the flowers in each head centripetal. Such is also the case in Figure 392, page 163. In Labiate plants, the general inflorescence is centripetal, while the verticillasters are centrifugal (Fig. 407).

224. Recapitulation of the different kinds of Inflorescence or Anthotaxis:—

1. Indefinite or Indeterminate Inflorescence, in which the floral axis is prolonged beyond the flowers, which are produced, either singly or in clusters, in the axil of leaves, the order of expansion being centripetal, *i.e.*, from the circumference towards the centre of the inflorescence, or from the base towards the apex.
2. The Indefinite Inflorescence may have unifloral or multifloral axillary peduncles.
3. In the Unifloral form the axis usually bears the single flowers in the axil of ordinary leaves. This is the simplest kind of Indefinite Inflorescence.
4. In the Multifloral form, the general peduncle, arising from an ordinary leaf or a modified leaf (bract) bears smaller leaves (bractlets), which produce flowers either sessile or pedicellate.
5. Multifloral peduncles, with sessile flowers, give origin to the various forms of spiked and clustered Indefinite Inflorescence, such as the Spike, Spikelet, Amentum, Spadix, Cone, and Capitulum.
6. Multifloral peduncles, with pedicellate flowers, give origin to the various forms of racemose, corymbose, panicled and umbellate Indefinite Inflorescence, such as the simple and compound Raceme, Corymb, and Umbel.
7. Definite or Determinate Inflorescence is that in which each floral axis ends in a solitary flower, and the order of expansion is centrifugal. The Cyme is considered as characteristic of this Inflorescence, and hence it is called Cymose.
8. The Definite Inflorescence may be either unifloral, *i.e.*, having a single primary axis ending in a flower, or it may be multifloral, having primary, secondary, and tertiary axes, &c., each ending in single flowers, but all combined, more or less so as to form a Compound Inflorescence.
9. The simplest form is the unifloral, in which the plant produces a single terminal flower, and no more.
10. The Multifloral forms are various, and their appearance depends on the lengths of the axes, and the mode in which they arise from each other.
11. When the different axes are elongated we meet with racemose, corymbose, and umbellate Cymes.
12. When the different axes are shortened, clustered kinds of inflorescence are produced, such as the Verticillaster, Fascicle, and Glomerulus.
13. Mixed Inflorescences combine the characters of the Indefinite and Definite; the separate clusters of Inflorescence exhibiting the character of the one, while the whole Inflorescence of the plant presents that of the other.
14. In all cases the Centripetal or Centrifugal expansion of the flowers, or of the clusters of flowers, indicates the nature of the Inflorescence.*

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* For a complete view of the different kinds of inflorescence, see Bravais, Essai sur la disposition symetrique des Inflorescences. Ann. des Sciences Naturelles, 2d Series, vii. 193, 291; viii. 11.

II. THE FLOWER AND ITS DIFFERENT PARTS.

1. SYMMETRY AND MORPHOLOGY OF THE FLOWER.

225. The term Flower, in botanical language, is not confined to the mere showy parts in which the gay and brilliant hues reside, but embraces all the organs, however inconspicuous, which are concerned in the production of seed. These organs, or parts of the flower, must all be considered as modifications, or, as it may be more properly expressed, *analogues* of leaves. In their structure and arrangement they are similar to the foliar organs, and they follow the same laws of development. When a student, therefore, has acquired a knowledge of the anatomy and arrangement of leaves, he is prepared to enter upon the consideration of the floral organs.

226. When the flower is complete it consists of four whorls (verticils), placed alternately within each other. The two internal are the *Stamens* and *Pistils*, which are the essential organs of reproduction, and the two external are the *Calyx* and *Corolla*, constituting the floral envelopes, or protective coverings. In Figure 408, an ideal section of a complete flower is given, each whorl consisting of five parts, which are arranged alternately. In Figures 409 and 410 the parts of the flower are represented; the calycine whorl (calyx), *s*, the corolline

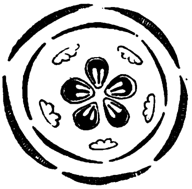

Fig. 408.

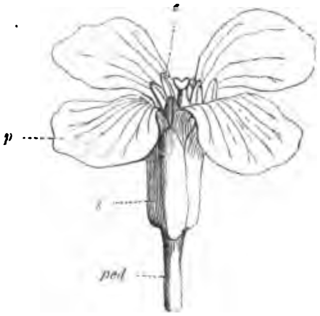

Fig. 409.

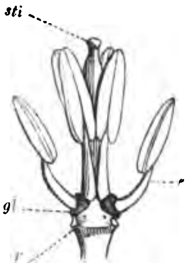

Fig. 410.

Fig. 408. Diagram of a completely symmetrical flower, consisting of four whorls, each consisting of five parts. The outer row is the calyx formed of five sepals; the second is the corolla of five petals, alternating with the sepals; the third is the andrœcium, consisting of five stamens, alternating with the petals; the central whorl is the gynœcium, consisting of five carpels, alternating with the stamens.

Fig. 409. Flower of Wallflower (*Cheiranthus Cheiri*). The stalk of the flower is called the peduncle, *ped;* the calyx, *s*, consists of four sepals; the corolla, *p*, is formed of four petals, arranged crosswise; the stamens, *e*, constitute the andrœcium or staminal whorl, and in the centre is the pistil.

Fig. 410. The Essential organs of reproduction of Wallflower. The stamens, *e*, are tetradynamous, *i.e.*, four long and two short, with glands, *gl*, at their base, and inserted into the receptacle or torus, *r;* the pistil is in the centre, and the summit of it, or the stigma, is marked, *sti*.

whorl (corolla), *p*, the staminal whorl (stamens), *e*, and the pistilline whorl (pistil), *sti*, being all inserted into a common receptacle, *r*, which may be considered as the termination of the peduncle, *ped*, or flower-stalk.

227. The Calyx is the outer covering (Fig. 409, *s*), formed of whorled leaves, called *sepals*, which are generally of a greenish colour. The Corolla is the next covering, composed of whorled leaves, called *petals* (Fig. 409, *p*), often showy, arranged alternately with the sepals (Fig. 408). The calyx and the corolla are sometimes included under the common name of *Perianth* or *Perigone*, especially in cases where both these coverings are similar in appearance, as in the Tulip, the Crocus (Fig. 160, p. 68), and the Lily (Figs. 411 and 413). A flower with a single perianth (Fig. 412) has a calyx only, while

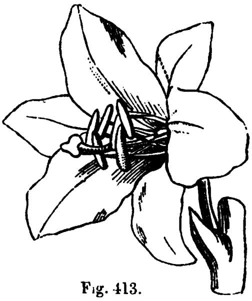

Fig. 413.

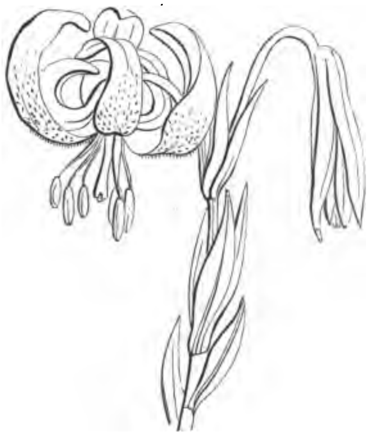

Fig. 411.

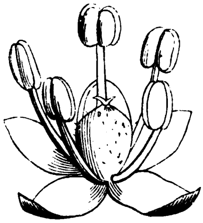

Fig. 412.

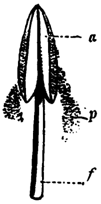

Fig. 414.

Fig. 411. The flowers of the scarlet Martagon Lily *(Lilium chalcedonicum)*. The three sepals and three petals are similar in colour, and collectively constitute the perianth or perigone. The stamens are six in number, in two rows, and the pistil is formed of three carpels. It is a Trimerous symmetrical flower. In the bud the two divisions of the perigone are seen. The plant appears to be the *Krinon* of the New Testament, mentioned in Matth. vi. 28, and in Luke xii. 27.

Fig. 412. Flower of Goosefoot (*Chenopodium*), consisting of a single perianth (calyx) of five parts, enclosing five stamens, which are opposite the divisions of the perianth, owing to the absence of the petals. The corolla being suppressed, the flower is apetalous, and as there is only one floral envelope it is called Monochlamydeous. In the centre of the flower is the pistil, with a large ovary containing young seeds.

Fig. 413. Flower of White Lily *(Lilium album)*, consisting of a six-leaved perianth, the parts of which are arranged in two alternate rows of three. The outer division of the perianth is in reality the calyx, with its three sepals, and the inner is the corolla, with three petals; but as they are similar in colour they are included in the term perianth. Within the floral envelopes are placed six stamens, in two rows of three each, and in the centre is the tricarpellary pistil.

Fig. 414. Stamen, consisting of a filament (stalk), *f*, and an anther, *a*, containing powdery matter, *p*, denominated pollen, which is discharged through slits in the two lobes of the anther.

one with a double perianth (Fig. 413) may be considered as having both calyx and corolla.*

228. The Stamens (Fig. 410, *e*) are placed within the petals, with which they alternate (Fig. 408). Each stamen consists of a peculiar folded leaf, called the *anther* (Fig. 414, *a*), either sessile (unstalked) or supported on a stalk, denominated a *filament* (Fig. 414, *f*), and containing powdery matter called *pollen* (Fig. 414, *p*), which is discharged through slits or holes. The whole staminal whorl, taken collectively, is styled the *Andrœcium*.

229. The Pistil is the central organ (Fig. 415), below and around which the other floral whorls are arranged. It consists of one or more folded leaves, called *carpels*, either separate (Fig. 416), or combined (Fig. 415), and collectively forming the pistilline whorl, which is denominated the *Gynœcium*. The parts distinguished in the pistil are the *ovary* (Fig. 415, *o*), which is the lower portion enclosing the

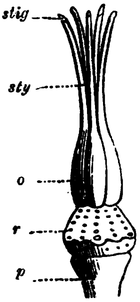

Fig. 416.

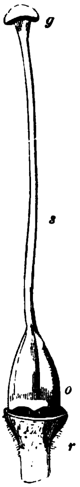

Fig. 415.

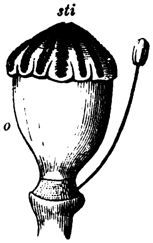

Fig. 417.

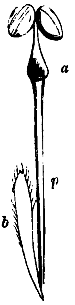

Fig. 418.

Fig. 415. The pistil of Tobacco (*Nicotiana Tabacum*), consisting of the ovary, *o*, containing ovules, the style, *s*, and the capitate stigma, *g*. The pistil is placed on the receptacle, *r*, at the extremity of the peduncle.

Fig. 416. The Gynœcium (Pistil) of Columbine (*Aquilegia vulgaris*), situated on the receptacle, *r*, which occupies the summit of the peduncle, *p*. The pistil consists of five carpels, each of which has an ovary, *o*, containing ovules, a style, *sty*, and a stigma, *stig*.

Fig. 417. Pistil of Poppy (*Papaver*), consisting of several carpels united. The united ovaries, *o*, are surmounted by the stigmas, *sti*, which are sessile, or, in other words, are not supported on a style. A single stamen is left to shew its insertion on the receptacle below the pistil (hypogynous).

Fig. 418. Male flower of Spurge (*Euphorbia*), consisting of a single stamen, *a*, without any envelope. The flower is hence called Achlamydeous. The peduncle, *p*, has a bract, *b*, at the base, and is united to the flower by a joint at *a*. This articulation indicates the nature of the flower. In some of the Euphorbias floral envelopes are produced at the joint. The solitary stamen constitutes the entire male (staminiferous) flower.

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* Some restrict the term perianth to cases where the envelope surrounds a staminiferous flower, while perigone is applied to the envelope of a flower having both stamens and pistil, or pistil only.

ovules destined to become seeds, the *stigma* (Fig. 415, *g*), a portion of loose cellular tissue, uncovered by epidermis, which is either sessile on the apex of the ovary, as in the Poppy (Fig. 417, *sti*), or is separated from it by a prolonged portion called the *style* (Fig. 415, *s*). The essential organs must be present, in order that seed may be produced, but the floral envelopes are often deficient. When both calyx and corolla are present (Fig. 409), the flower is *Dichlamydeous*, when the corolla is awanting (Fig. 412), the flower is *Monochlamydeous*, and when both are wanting (Fig. 418), it is *Achlamydeous*.

230. All the organs of the flower are attached to the extremity of the flower-stalk, and the part on which they are situated has received the names of *Thalamus*, *Torus*, and *Receptacle* (Figs. 410, *r*, and 416, *r*). The different organs are verticillate leaves, produced at nodes which are placed close to each other, without the intervention of marked internodes. Each organ forms one or more whorls, and the parts of each whorl are placed alternately in relation to those of the

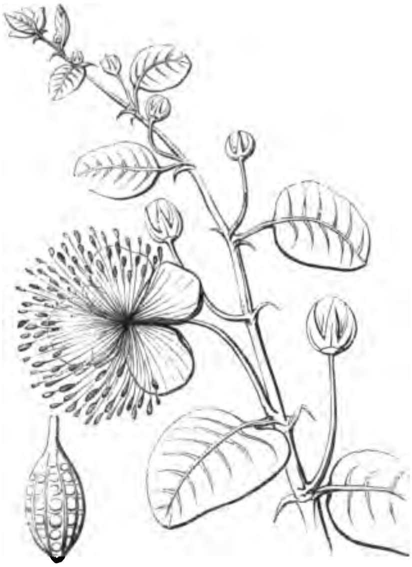

Fig 419.

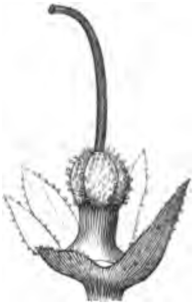

Fig. 421

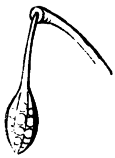

Fig. 420.

Fig. 419. The Caper plant (*Capparis spinosa*), shewing an expanded flower, and several flower-buds, which constitute the capers of commerce. In this plant the pistil represented in the figure on the left, is supported on a stalk or Gynophore, which is an elongation of the receptacle. There are numerous spines on the plant. These are either abortive leaves or abortive flower-stalks. This plant or another species of Caper (*Capparis ægyptiaca*), is supposed to be the Hyssop of Scripture —the *Esobh* of the Old Testament, and the *Hyssopos* of the New Testament. (Exod. xii. 22; Lev. xiv. 4, 6, 52; Numb. xix. 6, 18; 1 Kings iv. 33; Psalm li. 7; John xix. 29; and Heb. ix. 19).

Fig. 420. The pistil of the Caper-plant, with the stalk or gynophore which supports it.

Fig. 421. Calyx and pistil of Fraxinella (*Dictamnus Fraxinella*). The pistil consists of several carpels, which are elevated on a stalk prolonged from the receptacle. The stalk is called Gynophore or Thecaphore. The long narrow prolongation at the upper part is the style, terminating in a stigma.

whorls next it. In certain instances the internodes are lengthened, and thus the different whorls are separated from each other, just as in verticillate leaves (Fig. 217, p. 101). Thus, in some plants of the Caper tribe, there is an enlarged, rounded, disk-like receptacle (anthophore), bearing the petals, from the centre of which arises a stalk or internode (androphore) bearing the stamens, and finally, another lengthened internode (gynophore), bearing the pistil. In this instance the separate nodes, with their whorled leaves, and the interposed internodes, are easily seen. Occasionally, while the internodes connected with the calycine, corolline, and staminal whorls are shortened, that below the pistilline

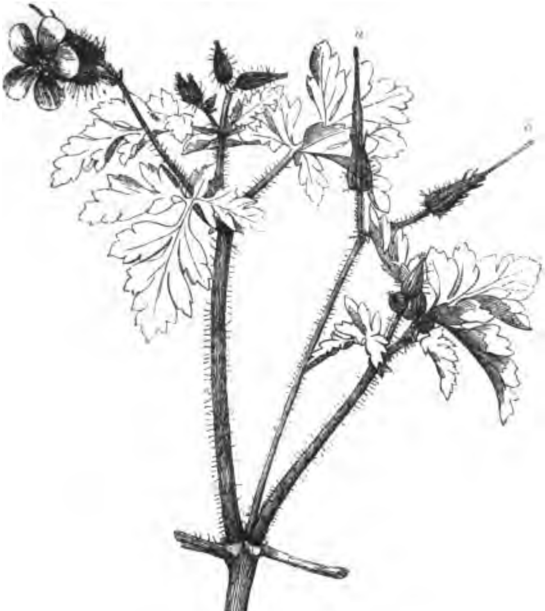

Fig. 422.

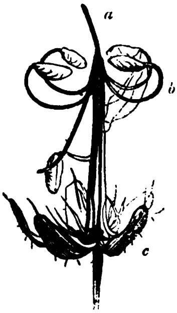

Fig. 423.

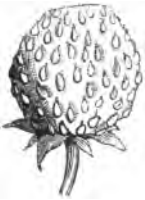

Fig. 424.

Fig. 422. Branch of a species of Cranesbill (*Geranium robertianum*), shewing at *a a* the beak-like process projecting beyond the flower, to which the carpels are attached.

Fig. 423. The calyx and beak-like process of Geranium, with the parts of the pistil (the carpels) curled upwards, so as to scatter the seed; *a*, the extremity of the rostrum or beak, whence the name crane's-bill is derived; *b*, the carpels curled up by means of the styles which are attached to the beak; *c*, the calyx.

Fig. 424. Fruit of the Strawberry (*Fragaria vesca*), consisting of an enlarged succulent prolongation of the receptacle, bearing on its surface numerous carpels, which are often erroneously called seeds. The calyx is seen at the lower part.

whorl is elongated. In such cases the pistil is supported on a stalk which proceeds from the centre of the receptacle. In the Caper-plant (Fig. 419), a stalked pistil occurs, which is represented in Figure 420. This is also the case in the Passion-flower, and in some of the Chickweed order, and in Fraxinella (Fig. 421). Such pistils are called *stipitate.*

231. In the Geranium, the part of the receptacle bearing the pistil is prolonged in the form of a long beak-like (rostrate) process, to which the styles are attached (Fig 422, *a*). When the pistil of the Geranium comes to maturity its parts separate from the beak, *a*, in the manner represented in Figure 423, *b*. In the Strawberry (Fig. 424) the receptacle, after giving origin to the calyx, corolla, and stamens, becomes enlarged and succulent, bearing the parts of the pistil on its surface, and constituting what is commonly called the fruit.

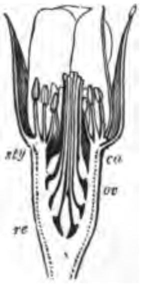

Fig. 425.

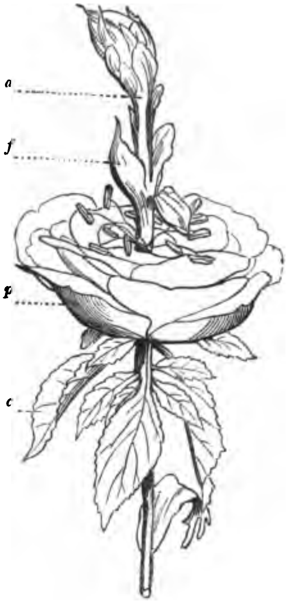

Fig. 426.

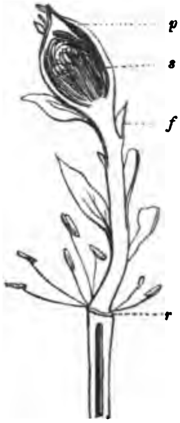

Fig. 427.

Fig. 425. The fruit of the Rose cut vertically. The receptacle, *re*, lines the interior of the calyx, *ca*, and the carpels with their ovaries, *ov*, and styles, *sty*, are attached to it. The stamens and petals are seen at the upper part, attached to the calyx.

Fig. 426. Monstrous flower of the Rose. The calyx, *c*, consists of sepals like the ordinary leaves; the corolla consists of numerous rows of petals, *p*; the stamens are partially changed into petals; the axis, *a*, is prolonged beyond the flower, bearing leaves, *f*, in place of carpels, and ending in an abortive flower-bud.

Fig. 427. The same monstrous rose, with the sepals and petals removed. The stamens are attached to the receptacle, *r*, which is prolonged in the form of a stalk bearing leaves, *f*, in place of carpels, and ending in a bud which contains abortive stamens, *s*, and undeveloped petals, *p*.

The sacred Bean of India and of the Nile (Nelumbium), has a large top-shaped (turbinate) receptacle enclosing the pistils. In the fruit of the Rose the portion of the receptacle (Fig. 425, *re*), bearing the parts of the pistilline whorl, *ov*, is adherent to the inner surface of the calyx, *ca*.

232. In some monstrous specimens of Avens and Rose there is occasionally an unusual development of the central part of the receptacle, so that the pistilline leaves become arranged alternately on an axis which ends in an abortive flower-bud. In Figures 426 and 427 representations are given of a Rose, in which the axis, *a*, is prolonged beyond the floral envelopes and stamens, *c p*, and bears the parts of the pistil in the form of alternate leaves, *f*, while at its extremity it produces a barren flower-bud, with undeveloped stamens, *s*, and abortive petals, *p*.

233. The leaves and the different parts of the flower are considered by botanists as homologous. In other words, they are constructed on the same plan, and the forms which they assume depend on the nature of the functions which they are required to perform. Leaves being concerned in nutrition and in the assimilation of food, assume an arrangement and colour fitted for these purposes, and have all their parts developed in conformity with the functions allotted to them. The parts of the flower, on the other hand, are concerned in the function of reproduction, and in their structure and development are fitted for the office which they have to perform. The parts of the flower originate in the same way as the leaves, in the form of simple cellular projections from the axis. The appearances which they afterwards present depend on organogenic (organ-producing) laws of development—the arrangement of the cells and vessels, and their contents being modified in each special organ.

234. The leaf is considered as the *type* of all. This idea was started by Linnæus, and was afterwards more fully brought forward by Goethe.* In speaking of the parts of the flower as metamorphosed or modified leaves, it must not be supposed that we mean that these parts have, at any period of their existence, been true leaves. All that is implied in the statement is, that both are formed on the same general plan, that both are arranged upon the same principle, and that one law pervades their morphology. The cell from which the leaf is formed is no doubt very different as regards the organogenic law impressed upon it from the cell which gives rise to a sepal, a petal, a stamen, or a carpel. Nevertheless, when we examine the parts scientifically, we perceive certain homologies in form and structure belonging to the one set of organs which are represented in the other. This morphological view of the organs of the flower associates

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* Linnæus, Prolepsis plantarum, Upsal, 1760; Amœnitat, Acad. vi.; Philosophia botanica. Wolf, Theoria generationis, Berlin, 1759. Goethe, Versuch die Metamorphose der Pflanzen zu erklären, Gotha, 1790. English Translation of Goethe's work, Pennsylv. 1830; also French Translation by Fred. de Gingins Lassaraz, Geneve, 1829. Linnæa vii. 1832. De Candolle Theorie elementaire de Botanique. Auguste de Saint Hilaire, Morphologie Vegetale; and Comptes rendus de l'Acad. des Sciences, 20th August 1838.

them with the leaves in a very interesting manner, and enables us to give a philosophical exposition of the harmonies subsisting between them.

235. In passing from leaves to flowers, there are certain intermediate organs called bracts (Fig. 338, *a*, p. 144, and Fig. 340, *a*, p. 145), which are merely altered or modified leaves, producing flower-buds at the part where they emerge from the stem. From these we proceed to the flower-stalks, which are branches bearing flower-buds in place of leaf-buds. The outer whorl of the flower (Fig. 426, *c*), has generally more or less of the appearance and colour of leaves, and, in many instances, the leaflets produced on the flower-stalk pass by insensible gradations into sepals (Fig. 369, p. 155). Between sepals and petals there are transition forms, as seen in the White Water Lily, the Magnolia, and many plants where the colour of both is similar. The petals, in their turn, sometimes become narrowed and altered, so as to pass into stamens, as in the White Water Lily, where it is scarcely possible to say where the different whorls end. It is very rare to find the stamens passing into the pistil. In the case of monstrosities, however, produced by cultivation, the pistil undergoes such changes as to prove that it is formed on the same type as the rest. Occasionally all the parts of a flower, as in some monstrous specimens of Dutch Clover, are converted into leaves.

236. When sepals are changed into petals, petals into stamens, or the latter into carpels, the alterations are said to be in the ascending series, and it is called a case of ascending or progressive metamorphosis. By cultivation, and other causes, this series of phenomena is sometimes reversed. Thus, in the double cherry, the pistil is frequently altered, so as to appear in the form of one or more leaves (Fig. 428, *a* and *b*); in double flowers the stamens are changed more or less completely into petals. In Figure 429 is exhibited the series of changes through which a stamen of the Rose passes, from the normal state, 6, until the complete petal, 2, is formed, and this, in its turn, becomes altered, as seen in 1, so as to resemble a coloured sepal, with a prominent and projecting midrib. In some cultivated flowers the petals assume a green colour, so as to resemble the calyx, which, in its turn, often appears like true leaves (Fig. 426, *c*). This is called retrograde metamorphosis.

237. In certain cases the floral axis, in place of bearing flowers, produces whorls of leaves. The alteration in such instances is either complete, or there is a partial change of the organs, some of them remaining unaltered. It sometimes happens that, from the centre of the flower, a leaf-bearing axis is prolonged at the expense of the pistil (Figs. 426 and 427, p. 178). Occasionally, after the fruit is formed, the axis begins to lengthen and bear leaves, as seen in the pear, represented in Figure 430. In the centre of the flower, or from the bases of the petals, additional flowers arise in certain instances, in the same way as buds come off from the axil of leaves. All these cases prove the general law of development in leaves and flowers to be in reality

the same, and they point out the means of explaining many of the anomalous appearances presented by the flower.

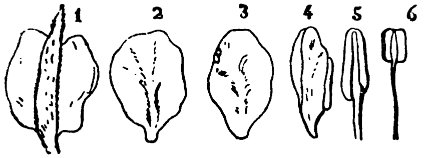
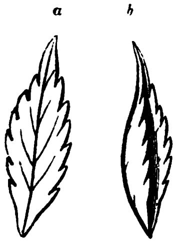


Fig. 429.



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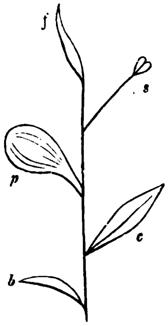

Fig. 431.

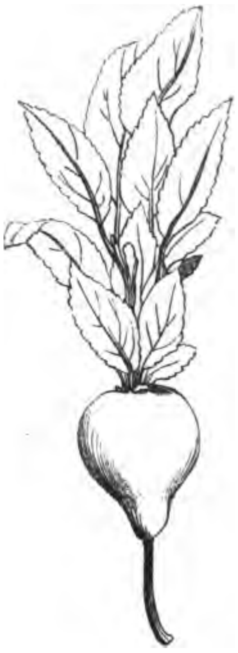

Fig. 430.

238. The parts of the flower being thus considered as modified leaves, we naturally look for a similar mode of arrangement. As leaves are alternate, opposite, and verticillate, we may expect the parts of the flower to be arranged in the same manner. We might conceive a flower, as in the ideal representation in Figure 431, to be formed of a sepal, *c*, a petal, *p*, a stamen, *s*, and a pistil, *f*; each of the parts alternating with that next to it, and separated by an internode, and all arising from a single bract, *b*. In plants such as Hippuris, with one stamen, and one pistil, and an abortive calyx, such may be reckoned the tendency, although, from non-development of certain parts, the

Fig. 428. The carpel of the double flowering Cherry. In this plant the fruit is abortive, and in its place one or more leaves are produced. The carpellary leaf is either expanded, *a*, or folded, *b*. This shows that the fruit of the Cherry is formed on the same type as the leaf.

Fig. 429. Transformations in the stamen of the Rose. The complete stamen, 6, is altered gradually, passing through the states represented at 5, 4, and 3, until it becomes a complete petal, 2, and the petal at 1 begins to assume the appearance of a sepal, with a strongly-marked midrib prolonged beyond the apex.

Fig. 430. The axis prolonged beyond the fruit in the Pear-tree, and bearing a series of leaves. In general the production of fruit arrests the axis.

Fig. 431. An ideal representation of a flower arising from a bract, *b*, and formed by a single sepal, *c*, a single petal, *p*, a single stamen, *s*, and a single carpel, *f*; the parts being alternate, and separated by internodes.

flower becomes incomplete. We generally find that the parts of the flower are arranged in twos, threes, fours, or fives.

239. When the parts of a flower appear in pairs, they may be considered as formed of opposite decussate leaves. In Figure 432, there is an ideal representation of such a flower, with its bracts, *b*, its sepals, *c*, petals, *p*, stamens, *s*, and carpels, *f*, separated by marked internodes. If the internodes in Figures 431 and 432 were taken away, or very much shortened, we would then have the arrangement usually seen in the flower. These diagrams also illustrate what occurs in the case of some plants, where (as already stated, ¶ 230), the different floral whorls are distant from each other. When the parts of a flower are arranged in threes, fours, or fives, they may, if placed in a circle at the same level, be regarded as verticils, or, if at different levels, as following a spiral arrangement.*

240. A flower is said to be *symmetrical* when each of its whorls consists of an equal number of parts, or when the parts of any one whorl are multiples of that preceding it. Thus, a symmetrical flower may have five sepals, five petals, five stamens, and five carpels, or the number of any of these parts may be ten, twenty, or some multiple of five. In Figure 408, page 173, there is a diagram of a symmetrical flower, with five parts in each whorl, alternating with each other. In Figure 433, there is a section of a symmetrical flower of Stone-crop, with five sepals, five alternating petals, ten stamens in two rows, and

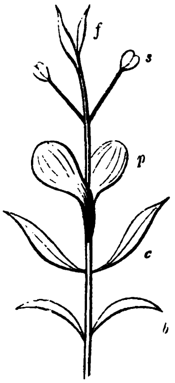

Fig. 432.

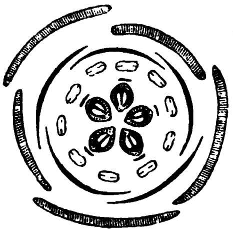

Fig. 433.

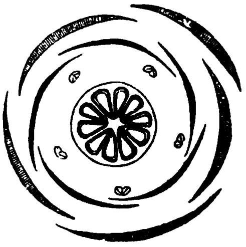

Fig. 434.

Fig. 432. An ideal representation of a dimerous flower, formed of two parts in each whorl. The bracts, *b*, the sepals, *c*, petals, *p*, stamens, *s*, and carpels, *f*. The parts of the flower are decussate, and thus follow a law of alternation. Each whorl is separated by an internode. If the internodes were removed the whorls would be closely applied to each other, as in ordinary flowers.

Fig. 433. Diagramatic section of a symmetrical pentamerous flower of Stone-crop (*Sedum*), consisting of five sepals externally, five petals alternating with the sepals, ten stamens in two rows, and five carpels containing seeds. The dark lines on the outside of the carpels are glands.

Fig. 434. Diagram of the flower of Flax (*Linum*), consisting of five sepals, five petals, five stamens, and five carpels each of which is partially divided into two. It is pentamerous, complete, symmetrical, and regular.

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* See paper by Brongniart in Annales des Sciences Nat. xxiii. 226.

five carpels. In Figure 434, there is a symmetrical flower, with five parts in the three outer rows, and ten divisions in the inner, caused by the partial subdivision of each of the five central parts into two. Figure 435, shows a flower of Heath, with four divisions of the calyx and corolla, eight stamens in two rows, and four divisions of the pistil. In Figure 436, there are three parts in each whorl; and in Figures 437 and 438, there are three divisions of the calyx, corolla, and pistil, and six stamens, in two rows. In all these cases the flower is symmetrical. Flowers in which the number of parts in each whorl is the same, are *isomerous* (equal number); when the number in some of the whorls is different, the flower is *anisomerous* (unequal number).

241. When the parts of any whorl are not equal to, or some multiple of the others, then the flower is *unsymmetrical.* This is seen in Veronica as given in Figure 439, where there are four divisions of the calyx, four of the corolla, and only two stamens, and two parts of the pistil; so also in Lamium and Verbena, Figures 440 and 441, where the two outer rows have five parts, and the two inner only four

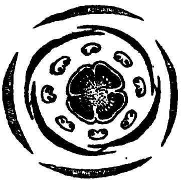


Fig. 435.

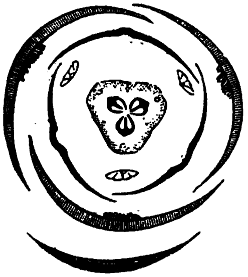


Fig. 436.

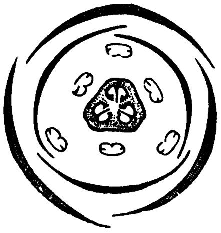


Fig. 437.

242. Symmetry, then, in botanical language, has reference to a certain definite numerical relation of parts. A flower, in which the parts are arranged in twos, is called *dimerous*, the symmetry being *binary*, and the arrangement marked thus $\surd^{2}$. This may be considered either as analogous to opposite decussating leaves (Fig. 212, p. 97), or as composed of distichous alternate leaves belonging to the $\frac{1}{2}$ series (Fig. 431), the internodes between which are undeveloped. When the parts of the floral whorls are three, the flower is *trimerous* (Figs. 437 and 438), and the symmetry being *ternary* or trigonal, is marked $\surd^{3}$. This may be looked upon as composed of verticillate leaves, or of tristichous alternate leaves, represented by $\frac{1}{3}$, the internodes between which are not developed.

243. When the floral pieces are in a series of four, the flower is

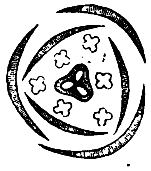
Fig. 435. Diagram of the flower of Heath (*Erica*), having four sepals, four divisions of the corolla, eight stamens in two rows, and four divisions of the pistil. The flower is tetramerous, complete, symmetrical, and regular.

Fig. 436. Diagram of the trimerous symmetrical flower of Iris. There are three alternating divisions of each whorl. Below is a single bract.

Fig. 437. Diagram of the symmetrical trimerous flower of Fritillary, having three divisions of the two outer whorls, and of the pistil in the centre, and six stamens in two rows.

tetramerous, its symmetry being *quaternary*, and marked $\surd^4$. It may be regarded as composed of verticils of four leaves, or of decussating leaves combined in pairs, without internodes. A *pentamerous* flower, marked $\surd^5$, has *quinary* or pentagonal symmetry, and may be formed of verticils of five leaves, or of alternate leaves, arranged according to the $\frac{2}{5}$ series (Fig. 211, p. 97), with undeveloped internodes. The symmetry which is most commonly met with in the vegetable kingdom is trimerous and pentamerous—the former occurring generally among Monocotyledons, the latter among Dicotyledons. Tetramerous symmetry occurs also among Dicotyledonous plants, and we shall afterwards see that the numbers 2 and 4 prevail in the reproductive organs of Acotyledons.

244. The parts of the flower are, generally speaking, arranged so that those of one whorl are alternate with those of the next whorl. Thus, the petals alternate with the sepals, the stamens with the petals, and so on (Fig. 408, p. 173). When the numbers in any series, such as the stamens, are multiplied, and the flower is still symmetrical, then the organ is found to consist of a definite number of whorls alternating with each other. Thus, in diagram 442, the stamens are six in place of three, and they are arranged in two alternating whorls—the parts of the outer whorl alternating with the petals, and with those of the inner series. In Figure 443, the stamens are ten, in two alternating rows of five each. In Figure 445, the parts of the flower of the Strawberry are shown, consisting of ten divisions of the calyx, in two alternating rows of five each, five petals, twenty stamens, in four alternating rows of five each, and numerous carpels also in similar rows. Figure 444 represents the flower of Ranunculus, with five sepals, five petals, numerous stamens and carpels, in alternating rows of five each.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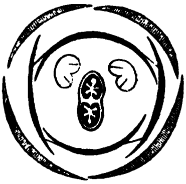
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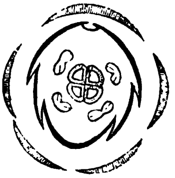
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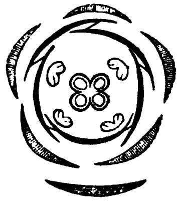


Fig. 441.

Fig. 438. Trimerous symmetrical flower of Woodrush (*Luzula*), showing an arrangement similar to that in Figure 437.

Fig. 439. Unsymmetrical flower of Speedwell (*Veronica*). The two outer whorls consists of four parts each, while the two inner have only two parts. The parts of the corolla are unequal, and the flower is therefore irregular.

Fig. 440. Unsymmetrical flower of Dead-nettle (*Lamium*). The two exterior whorls have five parts, while the two interior have only four, owing to the permanent abortion of one part in each. The parts are also unequally united, so as to render the flower irregular. One division of the calyx is superior, and two inferior, and the reverse is the case in the corolla.

Fig. 441. Diagram of the unsymmetrical flower of Vervain (*Verbena*). The two outer whorls have five parts, the two inner only four. A bract is represented below the flower.

245. The pistilline whorl is more liable to changes than the other parts of the flower. It frequently happens, that when it is fully formed, the number of its parts is not in conformity with that of the other whorls. In such circumstances, however, a flower is still called symmetrical, provided the parts of the other whorls are normal. Botanists are in the habit of neglecting the permanent state of the pistil in determining symmetry. Thus, Figures 446 and 448 show pentamerous symmetrical flowers, with dimerous pistils. Figure 447 is the diagram of a pentamerous symmetrical flower, with a trimerous pistil.

246. The various parts of the flower have a certain definite relation to the axis. The terms superior and inferior have reference to their position. Thus, in axillary tetramerous flowers (Fig. 449), one sepal is next the axis, and is called *superior* or *posterior;* another next the bract, is *inferior* or *anterior*, and the other two are *lateral;* the petals (when present) being alternate with the sepals, are so placed, that two are posterior, and two anterior; while the four stamens are arranged like the sepals. In a pentamerous flower it happens, that either one sepal is superior, two inferior, and two lateral, as in the calyx of Rosaceæ (Fig. 450), and Labiatæ (Fig. 440); or two are superior, one inferior, and two lateral, as in the calyx of Leguminosæ (Fig. 451). The reverse, of course, by the law of alternation, is the case with the petals. Thus, in the blossom of the Pea (Fig. 452), the odd petal (vexillum), *st*, is superior, while the odd sepal is inferior. In the Figwort order one of the two carpels is posterior, and the other anterior, as represented in the centre of Figure 453.

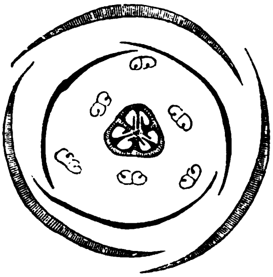
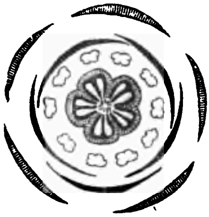


Fig. 442.



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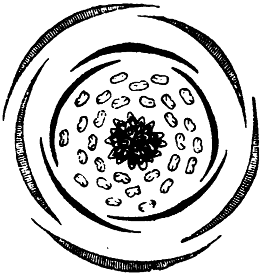


Fig. 444.

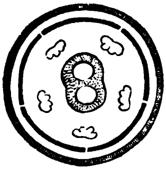
247. A flower normally consists of four whorls, calyx, corolla,

Fig. 442. Diagram of the flower of Snow-flake (*Leucojum*), consisting of three parts of the two outer whorls, six stamens in two alternating rows, and three carpels. The flower is symmetrical, complete, regular, and trimerous.

Fig. 443. Diagram of the flower of Rue (*Ruta*), consisting of five parts of the calyx, five of the corolla, ten stamens in two alternating rows, and five carpels. The flower is symmetrical, complete, and pentamerous.

Fig. 444. Diagram of the symmetrical pentamerous flower of Crowfoot (*Ranunculus*). The sepals and petals are five, the stamens and carpels are numerous (indefinite), in alternating rows of fives.

stamens, and pistil, and, when these are all present, the flower is *complete.* When each whorl consists of the same number of parts, or of a multiple of the parts, successively alternating with one another, we have seen that the flower is *symmetrical.* When the different parts of each whorl are alike in size and shape, the flower is *regular.* The absence of any of the whorls renders the flower *incomplete,* as in Figure 454, where the corolla is absent; in Figure 455, where the corolla and stamens are awanting; in Figure 449, where the corolla and pistil are deficient; and in Figure 418, p. 175, where calyx, corolla, and pistil, are awanting. Want of correspondence in the number of the parts of the whorls causes want of symmetry, as has been already shown, while differences in the size and shape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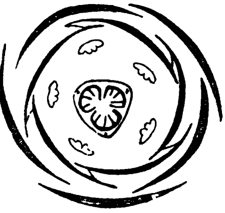
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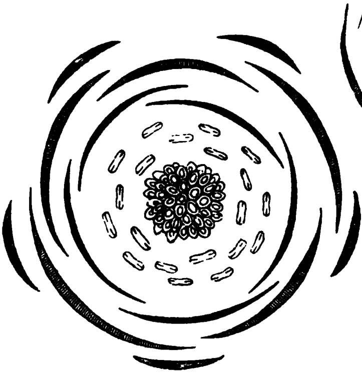


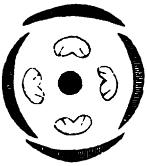


Fig. 449.

Fig. 445.

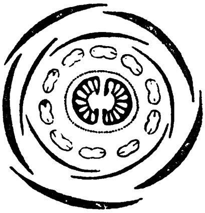


Fig. 448.

Fig. 445. Diagram of the symmetrical pentamerous flower of the Strawberry (*Fragaria vesca*). The calyx consists of two whorls of five parts each, the outer being called the epicalyx; there are five petals; the stamens are about twenty, constituting four alternating rows of five stamens each; the carpels are very numerous, but are some multiple of five, and are arranged in alternating rows.

Fig. 446. Flower of Madder (*Rubia tinctoria*). The outer circle is the obsolete calyx, with its parts united; there are five petals and five stamens, while the parts of the pistil are only two (dimerous). The flower is, nevertheless, said to be symmetrical.

Fig. 447. Diagram of flower of Greek Valerian (*Polemonium cæruleum*), having five divisions of the calyx and corolla, five stamens, and only three parts of the pistil. The flower is called symmetrical, although the carpellary whorl does not correspond in number with the others. The three outer whorls are pentamerous, the central one is trimerous.

Fig. 448. Diagram of the flower of Saxifrage (*Saxifraga tridactylites*). The calyx and corolla consist of five parts, the stamens are ten in two rows, while the pistil has only two parts developed. The flower is, nevertheless, called symmetrical, although the outer whorls are pentamerous, and the central one dimerous.

Fig. 449. Tetramerous male (unisexual) flower of the Nettle (*Urtica*). It is incomplete, as it wants petals and pistil; and it is said to be monochlamydeous. One sepal is next the axis, and is called posterior or superior, another is next the bract, called anterior or inferior, and two are lateral, that is, to the right and left of the axis. This is the usual occurrence in normally tetramerous flowers. In plants, however, such as Veronica, belonging to a natural order where the normal number is five, there are often irregularities.

of the parts of a whorl makes the flower *irregular*, as in the papilionaceous flower represented in Figure 452.

248. In their earliest stage of development all the parts of the floral whorls are regular and symmetrical, consisting of similar minute cellular papillæ arising from the axis. The alterations in their regularity and symmetry depend on changes taking place during their growth.[*] These alterations depend on the adhesion of one part to another, the union of different whorls, irregular growth, complete suppression of one or more parts or whorls, degeneration or degradation, multiplication of parts, and chorisis or deduplication.

249. A flower becomes incomplete by the non-development, or by the transformation of one or more whorls. It becomes irregular by one or more parts of a whorl being enlarged or diminished in size, and by irregular cohesions; and it becomes unsymmetrical when some of the parts of one or more whorls are suppressed, so that their numerical relations do not correspond. Thus, in Figure 457, by the disappearance of the whorl of stamens, the flower becomes incomplete, and, in Figure 456, the same thing takes place by the suppression of the pistil. By the difference in the form and size of the parts of the corolla of a Pea (Fig. 452), the flower becomes irregular, and, by the non-development of a stamen in the Dead nettle (Fig. 339, p. 145, and Fig. 440, p. 184), the flower is unsymmetrical.

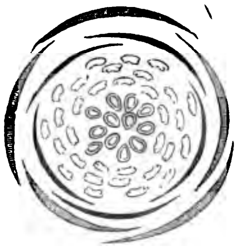
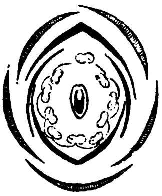


Fig. 450.



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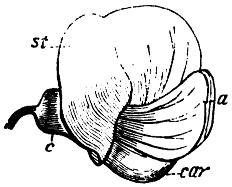

Fig. 452.

250. The consideration of all the changes which the parts of plants undergo, or, in other words, the permanent deviations from what may be considered as their normal state, is included under the

Fig. 450. Diagram of flower of Rose, showing one division of the calyx superior or next the axis, and two inferior or next the bract. The petals are arranged alternately with the calycine segments, and hence two of them are superior, and one inferior.

Fig. 451. Diagram of flower of Sweet-pea (*Lathyrus*), showing five parts of the calyx, of which two are superior, one inferior, and two lateral; five parts of the corolla, of which one is superior, two inferior, and two lateral; ten stamens in two rows; one carpel, in consequence of four being undeveloped.

Fig. 452. Flower of Pea (*Pisum sativum*), showing a papilionaceous corolla, with one petal superior, *st*, called the standard (vexillum), two inferior, *car*, called the keel (carina), and two lateral, *a*, called wings (alæ). The calyx is marked *c*.

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[*] Barneoud sur l'organogenie des corolles irrégulières. Ann. des Sciences Nat. 3 ser. Bot. viii. 344.

term Teratology.* Every alteration in the organs of the flower may be traced to the morphological laws to which we have already alluded. In treating of the separate floral whorls, notice will be taken of the changes which they undergo; in the meantime some general remarks will be made on the causes to which these changes are referred.

251. *Union* or *adhesion* of the floral whorls, or of the parts composing them, gives rise to various changes in form and symmetry. The adhesion is sometimes very irregular, so that certain parts are more completely united than others. Many forms of irregular flowers are due to this cause. The *non-development* of whorls gives incompleteness to the flower. The absence of the corolline whorl renders a flower *apetalous* or *monochlamydeous* (Fig. 412, p. 174, and Fig. 454), the absence of both the calycine and corolline whorl makes the flower *naked* or *achlamydeous* (Fig. 418, p. 175). The suppression of the stamens (Fig. 455), or of the pistil (Fig. 456), renders the flower *unisexual*. The non-appearance of a whorl deranges the relation of the different parts, and destroys their alternation.† Thus, in the apetalous flower of the Nettle (Fig. 449, p. 186), the stamens, in place of being alternate with the whorl on their outside, are opposite to it,

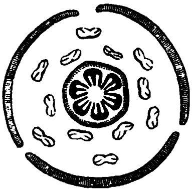


Fig. 454.

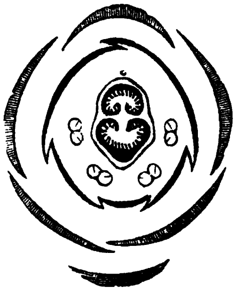
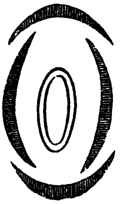


Fig. 453.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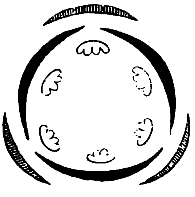
Fig. 456.

Fig. 453. Diagram of flower of Frogsmouth (*Antirrhinum*). The flower is unsymmetrical and irregular. Below is represented a single bract. There are five divisions of the calycine whorl, and five of the corolline, but the parts are unequal; there are only four stamens, one being abortive, as represented above the pistil; the pistil consists only of two carpels, one being superior, and the other inferior (next the bract). In the calyx one part is superior, two inferior, and two lateral; while in the corolla, two are superior, one inferior, and two lateral.

Fig. 454. Diagram of the flower of Asarabacca (*Asarum europæum*). The flower is incomplete, owing to the absence of petals. It is called monochlamydeous. The arrangement is trimerous, there being three divisions of the calyx, nine stamens in three rows, and six carpels.

Fig. 455. Diagram of the female flower of the Nettle (*Urtica*). It is monochlamydeous (with calyx only), and incomplete, as the petals and stamens are absent. The flower is unisexual.

Fig. 456. Incomplete flower of a Fan Palm (*Chamærops*). The pistil is suppressed, so that the flower is unisexual, and male or staminiferous. The flower is trimerous.

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* For a full view of this subject, consult Moquin-Tandon, Tératologie Végétale, and Martins, de la Tératologie Vegetale, Montpellier, 1851.

† The change in the alternate arrangement of the parts may be said to give rise to a want of symmetry, even although the parts which remain correspond in number. In this sense symmetry would include both the number and the arrangement of the parts of different whorls.

and this relation of parts leads to the detection of the suppressed whorl. So also, in Geranium (Fig. 458), the outer row of stamens is opposite the petals, showing that there is a still more external whorl suppressed, as indicated in the figure by the black dots. It will thus be seen that many anomalies in this arrangement of the floral verticils may be accounted for by changes such as those we have mentioned.

252. Various parts of the flower are apt to become abnormal, or degenerate by *transformations* of different kinds. Some of the parts may be converted into scales or into hairs. The floral leaves of the catkin of the Willow (Fig. 348, p. 148), and those of the Hop (Fig. 352, p. 149), are membranous scales, while those of the Cone (Fig. 353, p. 150), are hard scales; the Wig-tree (Fig. 368, p. 154) produces hairs instead of flowers on some of its peduncles, and the calyx of the Dandelion, and other compound flowers (Fig. 365, p. 154), assumes the form of hairs, which remain attached to the fruit. In double flowers the stamens and pistils degenerate by being converted into petals.

253. Sometimes the parts of a flower are increased in number by the growth of additional parts, or by the splitting of organs during their development. This latter process is called *Chorisis*, and seems to account satisfactorily for the appearance of certain anomalous parts which do not follow the law of alternation. This chorisis (separation) consists in the formation of two parts out of one, the separated parts being either placed one in front of the other by transverse chorisis, or side by side by collateral chorisis. The lamina of a petal may be split

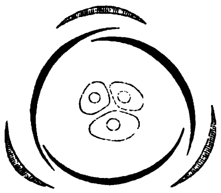


Fig. 457.

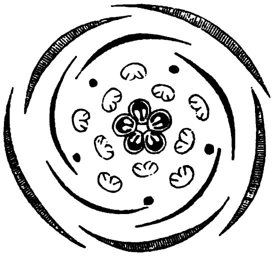


Fig. 458.

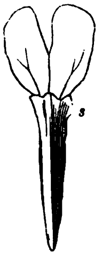


Fig. 459.

Fig. 457. Incomplete flower of a Fan Palm *(Chamærops)*. The stamens are suppressed, so that the flower is unisexual, and female, or pistilliferous. The flower is trimerous.

Fig. 458. Diagram of the flower of Geranium, showing five parts of the calycine and corolline whorls, ten alternating perfect stamens in two rows, and five carpels. The outer row of stamens is, however, opposite to the petals, in place of being alternate, and consequently there is a row absent to make up the perfect symmetry. The undeveloped row is marked by black dots. It appears in the form of five abortive stamens. The relation of the different parts of a flower thus leads to the detection of abnormalities.

Fig. 459. Forked petal of Rose-campion (*Lychnis*), showing a lamina, *s*, detached from it, and standing opposite to it. This scale on the petal is supposed to be produced by transverse chorisis or dilamination. Had the scale been alternate with the petals, it would have been looked upon as an abortive state of another whorl. The petal has a narrow part below, which is called an unguis or claw.

in such a way that a scale is produced on part of it, as seen in Lychnis (Fig. 459, *s*) ; stamens may be divided so that two standing collaterally are produced in place of one. In this way some account for the abnormal state of the stamens in cruciferous flowers, such as Stock and Wallflower (Fig. 410, p. 173, and Fig. 460). In these plants, while the calyx and corolla consist of four parts, the stamens are six, owing, it is said, to collateral chorisis of two of them. The flowers are thus considered normally tetramerous. In the Fumitory (Fig. 461), there are two sepals, four petals in two rows, and six stamens. The latter consist of two perfect stamens, and four incomplete, which are considered as being produced by collateral chorisis of two stamens. In this way the flower would be normally dimerous. When the parts of contiguous floral whorls are opposite to each other, in place of being alternate, the occurrence may be accounted for, either by suppression of a whorl, or by chorisis. The scales in Figure 433, marked by lines within and opposite the stamens, may be traced to chorisis, so also the arrangement of stamens, in Figure 462. Collateral chorisis may be considered as equivalent to the division of a leaf into a number of separate leaflets, each resembling the other, while transverse chorisis may have its analogue in the ligule of grasses (Fig. 317, p. 136). There are many anomalous changes in flowers which depend on cultivation. Such monstrosities, however, will be easily accounted for by bearing in mind the morphological laws on which these metamorphoses depend.

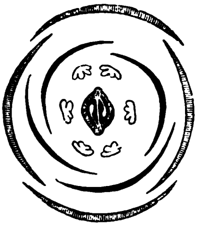


Fig. 460.

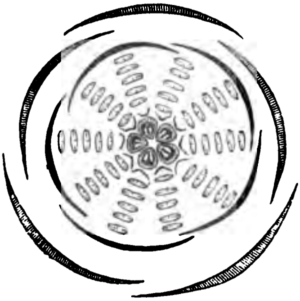


Fig. 462.

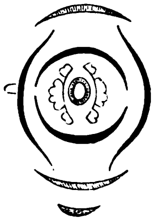


Fig. 461.

Fig. 460. Diagram of the flower of the common Stock (*Matthiola incana*). The calycine whorl consists of four parts, the corolline also of four, but the stamens are six, of which four are long and two short. The four long are placed together in pairs, as shown in the diagram, and some suppose that each pair is originally one stamen, which splits into two by collateral chorisis. The divisions of the pistil are two, a state which some consider as being produced by the abortion of other two carpels. The flower is thus considered as being normally tetramerous.

Fig. 461. Diagram of the flower of Fumitory (*Fumaria*). A bract is represented below, then two segments of the calyx, then four parts of the corolline whorl, in two rows, then six stamens, and one carpel forming the pistil. Of the six stamens two only are perfect, and the other four are imperfect, having only one antherine lobe. Some suppose, therefore, that these four imperfect stamens are in reality produced by the collateral chorisis of two perfect ones. The stamens may thus be considered four in two rows, and the flower would then be called dimerous.

Fig. 462. Diagram of flower of Columbine (*Aquilegia vulgaris*), in which there are five sepals, and five alternating petals, numerous stamens (multiple of five), and five carpels. The rows of stamens being placed opposite, in place of alternate, are considered as formed by transverse chorisis.

2. THE FLOWER-BUD.

254. The various parts of the flower consisting of the floral envelopes, and the essential organs of reproduction are contained in the flower-bud. They appear at first in the form of small cellular mammillæ, or prominences, the parts of each verticil being equal and separate. In their development (organogeny) they follow the same order as leaves—the extremities of each of the parts being first formed, and irregularities, caused by adhesion and other causes, occurring only during the progress of growth. In general the whorls are developed successively, from the calyx to the pistil; but, in some instances, the petals are retarded in their growth, so that the stamens are completed before them.

255. The terms *Præfloration* and *Æstivation* are used to express the arrangement of the different parts of the flower in the flower-bud. The relation of these parts to each other is similar to that which occurs in the leaf-bud, and which has been considered under præfoliation (¶ 153). The same terms are also used to express the nature of many of these arrangements. As regards each leaf of the flower, it is either spread out, as the sepals in the bud of the Lime tree, or folded upon itself (conduplicate), as in the petals of some species of Lysimachia, or slightly folded inwards or outwards at the edges, as in the calyx of some species of Clematis, and of some herbaceous plants, or rolled up at the edges (involute or revolute), or corrugated and crumpled, as the petals of the Poppy (Fig. 463).

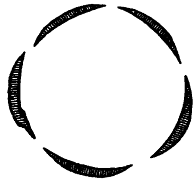


Fig. 464.

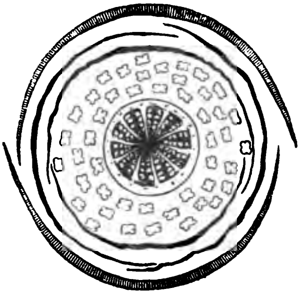


Fig. 463.

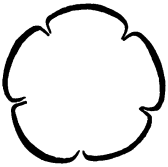


Fig. 465.

256. The position of the parts of the flower relative to each other, in the bud, gives origin to the terms *valvular*, *contortive* or *twisted*, and

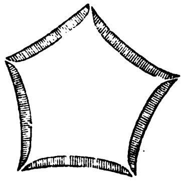
Fig. 463. Diagram of the flower of Poppy (*Papaver*), shewing two sepals placed externally and arranged in an obvolute manner, four crumpled petals, arranged alternately in pairs, numerous stamens, arranged in verticils, and ten divisions of the pistil. All the parts are multiples of two, and the flower may be called dimerous.

Fig. 464. Diagram to illustrate Valvular or Valvate æstivation, in which the parts are placed in a circle, without overlapping or folding.

Fig. 465. Diagram to illustrate Induplicative or Induplicate æstivation, in which the parts of the verticil are slightly turned inwards at the edges.

imbricated. In the first two the parts are placed at the same level, in a circular manner, while in the latter they are at different heights, and follow a distinctly spiral order. The æstivation is *valvular*, or the parts are arranged in a valvate manner (Fig. 464), when they are so applied as to be in contact at their edges without any folding. They are in a circular verticil. When the parts of the verticil are slightly folded inwards at their edges the æstivation is *induplicative* (Fig. 465), when folded outwards *reduplicative* (Fig. 466). When the parts of the corolla are united they are occasionally folded in a plaited manner.

257. In *Contortive* æstivation the parts are in a circle, or apparently so, and one edge of each is directed inwards, so as to be overlapped by the contiguous part, while the other edge covers the margin of the part adjacent on the other side; each part also is, as it were, twisted on its axis, and the whole whorl exhibits a convolute appearance (Fig. 467). It is well seen in the unexpanded petals of Malvaceous plants (Fig. 468), in the corolla of Cyclamen (Figs. 469 and 470), and in that of many Apocynaceæ, which were called Contortæ by old authors.



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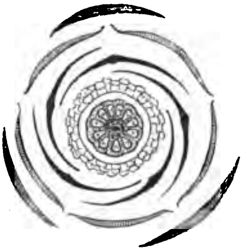

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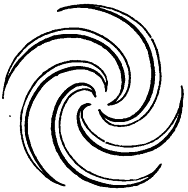


Fig. 467.

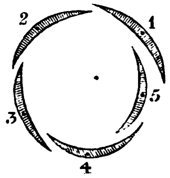
258. The æstivation called *imbricated* or *imbricative*, embraces those bud arrangements in which the parts are placed at different heights so as to overlie each other, and form a more or less evident spiral cycle (Fig. 471). When the parts of a floral whorl are five, as is the case in many Exogens, it is often found that there are two parts wholly on the outside, two completely internal, and one intermediate, overlapped at one edge by one of the outer parts, whilst its other edge covers one of the inner parts (Fig. 472). This is *quin-*

Fig. 466. Diagram to illustrate reduplicative or reduplicate æstivation, in which the parts of the whorl are slightly turned outwards at the edges.

Fig. 467. Diagram to illustrate contortive or twisted æstivation, in which the parts of the whorl are overlapped by each other in turn, and are twisted on their axes. This is common in the Mallows.

Fig. 468. Diagram of flower of Mallow, in which there are three outer sepals, forming the epicalyx, five inner sepals, arranged in a somewhat reduplicate manner, and five petals, each of which is partially covered by that next to it, and in its turn overlaps its neighbour, the whole being twisted on their axis. Numerous stamens and carpels occupy the centre, the stamens being united by their filaments.

cuncial or *spiral* imbrication, and is the normal arrangement in pentamerous flowers, corresponding with the $\frac{2}{5}$ arrangement in leaves. In personate flowers, as Frogsmouth, a variety of imbricated æstivation occurs, called *cochlear* (Fig. 473), in which the second part of the cycle, in place of being external (as in the ordinary quincuncial arrangement), becomes wholly internal. When imbricated æstivation occurs in trimerous flowers (Fig. 474), there is one part outside, one inside, and one intermediate, the arrangement being $\frac{1}{3}$, as in leaves. When the flower is tetramerous (Fig. 475), there are two outer parts and two inner parts; this being analogous to what occurs in opposite decussating leaves. In pea-like blossoms (Fig. 452, p. 187), it is usual to find a modification of imbricated æstivation, called *vexillary*, in which the large petal called the vexillum, and which is superior or next the axis, overlaps the rest (Fig. 476). In some instances, as in the Judas-tree, the vexillum is included between the lateral petals (alæ), as represented by the dotted lines, 4, Figure 476. The different



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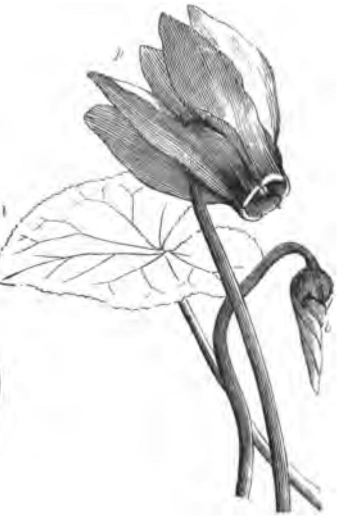

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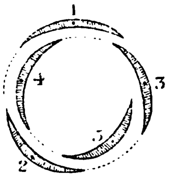

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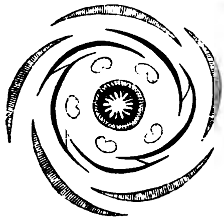

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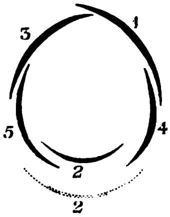


Fig. 473.

Fig. 469. Expanded flower, flower-bud, and leaf of the Sowbread (*Cyclamen europæum*). The leaf, *l*, is sagittate-cordate, the petals of the flower, *p*, are reflexed, and those in the bud, *b*, are contorted, so as to exhibit twisted æstivation.

Fig. 470. Diagram of the flower of the Sowbread (*Cyclamen*), shewing the five sepals overlapping each other in turn, and five petals arranged in a contortive manner, five stamens, and the pistil in the centre.

Fig. 471. Diagram to illustrate imbricative or imbricated æstivation, in which the parts are arranged in a spiral cycle, following the order indicated by the figures 1, 2, 3, 4, 5.

Fig. 472. Diagram to illustrate the quincuncial æstivation, in which the parts of the flower are arranged in a spiral cycle, so that 1 and 2 are wholly external, 4 and 5 are internal, and 3 is partly external and partly overlapped by 1. This is common in pentamerous flowers.

Fig. 473. Diagram of cochlear æstivation, in which the petal 2 is wholly internal, in place of being external. Its normal position in the imbricate æstivation is indicated by the dotted line.

verticils of the flower have not always the same æstivation. In the Mallow tribe (Fig. 468, p. 192), the calyx is valvate, while the corolla is twisted; in St. John's Wort (Fig. 477) the calyx is imbricated and the corolla twisted; in the Rock-rose (Fig. 478) the three inner sepals are twisted in one direction, while the petals are twisted in an opposite direction.

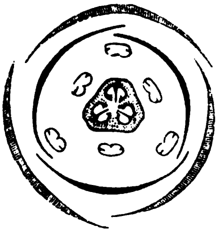
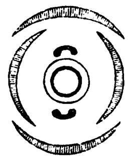


Fig. 474.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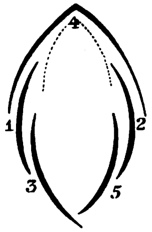

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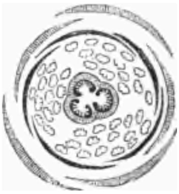
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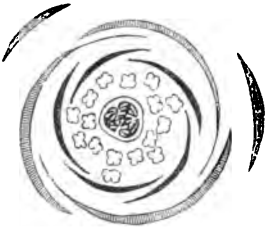
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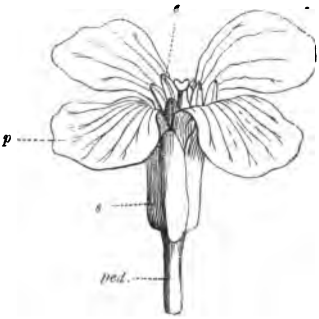

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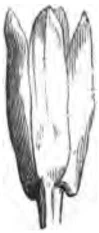


Fig. 480.

Fig. 474. Diagram of imbricate æstivation in a trimerous flower (*Fritillaria*), in which one part is outside, one inside, and one intermediate, the latter partially overlapping the inner part, and being in its turn partially overlapped by the outer.

Fig. 475. Diagram of a flower having four parts, of which two are outer, overlapping the edges of the two inner.

Fig. 476. Diagram of a papilionaceous flower, shewing vexillary æstivation, 1 and 2 the alæ or wings, 3 a part of the carina or keel, 4 the vexillum or standard, which, in place of being internal, as marked by the dotted line, becomes external, 5 the remaining part of the keel. The order of the cycle is indicated by the figures.

Fig. 477. Diagram of the flower of St. John's Wort (*Hypericum*), in which the sepals and petals are imbricated, and the latter are contorted. The stamens are numerous in three bundles, and there are three divisions of the pistil.

Fig. 478. Diagram of the flower of the Rock-rose (*Helianthemum*), in which there are two outer sepals and three inner ones, the latter being twisted in one direction, while the five petals are twisted in the opposite direction. The stamens are numerous, the pistil in the centre shews three divisions.

Fig. 479. Flower of Wallflower (*Cheiranthus Cheiri*), shewing the peduncle, *ped*, the calyx composed of four sepals, *s*, the corolla of four petals, *p*, and the stamens, *e*.

Fig. 480. The calyx of Wallflower separated, shewing the four sepals, two of which are gibbous at the base, *i.e.*, exhibit slight projections or swellings.

3. THE FLORAL ENVELOPES.

A. *The Calyx or Outer Floral Envelope.*

259. The Calyx is the outer floral envelope, and is composed of a whorl of leaves called *Sepals* (Figs. 479, *s*, and 480). These leaves have usually the structure and appearance of ordinary leaves, as regards the distribution of their cells and vessels. They are frequently of a greenish hue, having chlorophyll in their cells, and stomata on their lower (outer) epidermal covering. In Gentiana campestris, and G. crinita, the sepals resemble the ordinary leaves of the plants. In proliferous states of the Rose (Fig. 481), Dutch Clover, Oriental Poppy, and Primrose, the calyx assumes a leafy form. In a specimen of Lycium europæum, Turpin noticed one sepal resembling the ordinary leaves; and in Mussænda macrophylla, one of the sepals is deve-

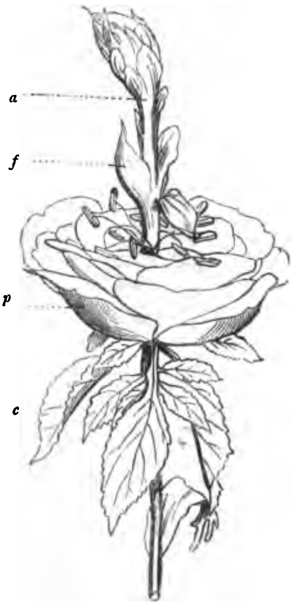


Fig. 481.

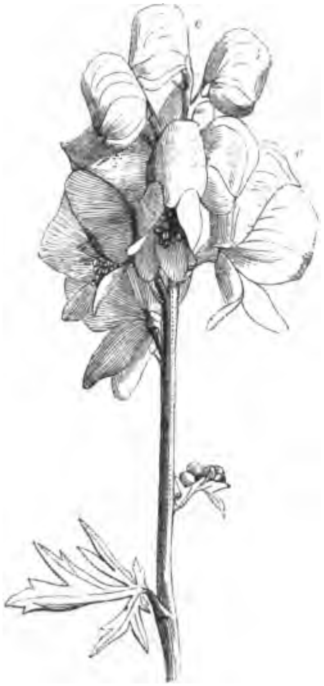


Fig. 482.

Fig. 481. Monstrous flower of the Rose, showing the calyx, *c*, with the sepals like true leaves, the petals, *p*, multiplied at the expense of the stamens, the carpels, *f*, transformed into coloured leaves, and the axis, *a*, prolonged, and bearing an abortive flower-bud.

Fig. 482. Flower of Monkshood (*Aconitum Napellus*), showing the peculiar helmet-shaped calyx, *c c*, which is of the same colour as the petals. It is called a coloured calyx.

loped as a large white leaf, while the others are small and green. When not green the calyx is said to be coloured, as in Columbine (Fig. 393, p. 164), in Monkshood (Fig. 482), Larkspur, Fuchsia, Indian-cress (Fig. 483), Lily (Figs. 411 and 413, p. 174), Iris, and Narcissus (Fig. 343, p. 147). In the three last mentioned plants, and in most monocotyledons, the name perianth (¶ 227) is applied to the calyx and corolla. In Fumitory (Fig. 522, p. 203), the calyx consists of two coloured scales.

260. It is not common to find the individual sepals divided. Sepals are usually sessile leaves, having no stalks. They are either distinct from each other, as in Wallflower (Fig. 479, *s*), or they are combined, as in the Melon (Fig. 484, *c*). When the sepals are separate the calyx is *polysepalous*, *polyphyllous*, or *dialysepalous*, the number of sepals being marked by the Greek numerals prefixed. Thus, disepalous means a calyx with two distinct sepals; trisepalous with three; tetrasepalous with four; pentasepalous with five; hexasepalous with six; or the Greek word *phylla*, meaning leaves, is used, and a disepalous calyx is denominated diphyllous, and so on.

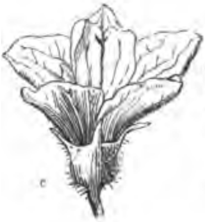
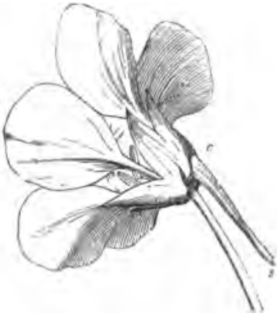


Fig. 484.



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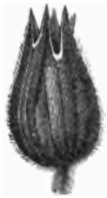

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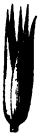


Fig. 486.

261. When sepals are united by adhesion, they form a *gamosepalous* or *gamophyllous* calyx, terms implying union of sepals or leaves, and therefore preferable to *monosepalous* and *monophyllous*, which mean literally one sepal or leaf. This adhesion of sepals varies in extent, and thus gives rise to the terms, *entire*, when the union is complete, and there are no division at the top, as in Correa, *toothed* (Fig. 485), *cleft* (Fig. 486), and *partite* (Fig. 487), when the divisions are mere toothings, extend to the middle, or to near the base. Thus, a gamosepalous calyx, as shown in the figures, may be five-toothed (quinque-dentate), five-cleft (quinquefid), or five-partite (quinque-partite),

Fig. 483. Flower of Indian Cress (*Tropæolum majus*), in which the calyx, *c*, is coloured, and three of its sepals are prolonged in the form of a spur, *s*, (calcar).

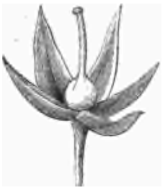
Fig. 484. Male flower of Melon (*Cucumis Melo*), showing a gamosepalous calyx, *c*, having tooth-like projections at the margin, and covered with hairs. The petals are five, beautifully veined, and imbricated in æstivation.

Fig. 485. Gamosepalous, five-toothed (quinque-dentate) calyx of Campion (*Lychnis*).

Fig. 486. Gamosepalous five-cleft (quinquefid) calyx of Centaury (*Erythræa*).

the number of divisions usually indicating the number of sepals of which the calyx is composed. In an entire gamosepalous calyx the venation assists in the determination of the number of sepals.

262. When the union of the sepals is not equal in all the parts, the calyx has an irregular form, as in Lathyrus (Fig. 488), and in Labiate flowers (Fig. 489). In the latter case the calyx is *two-lipped* (bilabiate), the upper lip being composed of three sepals, one of which is either arched or stands out from the rest in a marked manner, and the lower lip being formed of two sepals. The united parts of a gamosepalous calyx form the *tube*, the free portions at the apex are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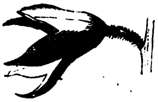
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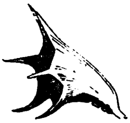
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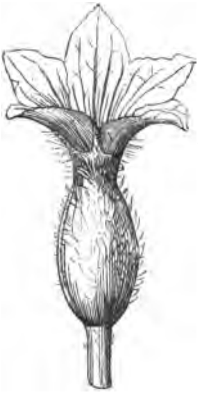
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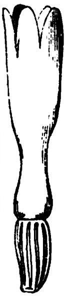
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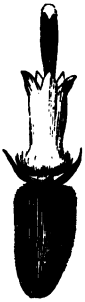
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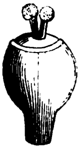
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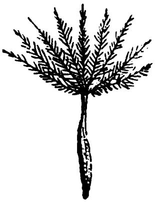


Fig. 494.

Fig. 487. Gamosepalous five-partite (quinque-partite) calyx of Pimpernel (*Anagallis*), surrounding the pistil, which is composed of ovary, style, and stigma.

Fig. 488. Irregular gamosepalous calyx of a species of Lathyrus. The sepals are united unequally, so as to form apparently two lips, the upper composed of two sepals, the lower of three.

Fig. 489. Bilabiate gamosepalous calyx of the Dead-nettle (*Lamium*). It is composed of two lips, the upper lip formed by three sepals, the lower by two. One of the upper sepals stands prominently out from the rest. The tube is formed by the united sepals, the free parts of the calyx forming the limb, and the opening being the faux or throat.

Fig. 490. Female flower of Melon (*Cucumis Melo*), showing the gamosepalous calyx united to the pistil, and forming part of the fruit. It is called an adherent calyx. It is also denominated superior, as the limb appears above the fruit. There are five beautifully veined imbricated petals.

Fig. 491. Tubular flower of Ox-eye (*Chrysanthemum*). The corolla is gamopetalous and regular, formed by five petals, the calyx is completely adherent to the single-seeded fruit below. There is no calycine limb visible.

Fig. 492. One of the central flowers of the Sun-flower (*Helianthus*). The corolla is gamopetalous, five-toothed at the apex, the calyx is adherent to the fruit, and the limb of the calyx appears above the fruit in the form of a membrane, with pointed projections. The calyx is called superior, because its free portion is above the fruit. Extending beyond the flower are seen the stamens and pistil.

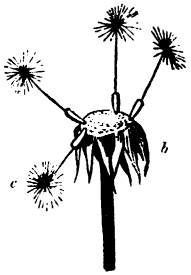
Fig. 493. Calyx of Madder (*Rubia*), adherent to the pistil, its limb appearing in the form of a rim. The calyx is called obsolete.

Fig. 494. Feathery pappus attached to the fruit of Salsafy (*Tragopogon porrifolius*). The calyx adheres to the fruit, and its limb is pappose.

the lobes or segments of the *limb*, and the orifice of the tube is the *throat* (faux).

263. The tube of a gamosepalous calyx frequently adheres more or less completely to the other whorls, especially to the pistil. In the latter instance the calyx remains persistent, and forms part of the fruit, as in the Apple, Pear, Gooseberry, Pomegranate, and Melon (Fig. 490). In such instances the limb of the calyx often becomes degenerate, and is either absent (Fig. 491), or appears in the form of scales or pointed projections (Fig. 492), or of a circular rim (Fig. 493), or of pappus, as in Composite flowers (Figs. 494 and 495). In the adherent calyx of Valerian (Fig. 496), the limb is at first a ring, but ultimately expands in the form of hairs (Fig. 497), and hence is called *pappose*.

264. The calyx may continue persistent, and yet be separable from the fruit, as in Henbane (Fig. 498), in Mallow (Fig. 499), and in the Peruvian Winter-cherry and other species of Physalis (Figs. 500 and 501), where it increases after the flower has withered, and surrounds the fruit like a bladder. It sometimes continues in a withered state, as in the Heath, and is called *marcescent*. The term *superior* is applied to the calyx or perianth when it is so united to the fruit as to appear to arise from its summit, as in Melon (Fig. 490), and Iris (Fig. 502). In the Rose (Figs. 503 and 504), the tube of the calyx bears numerous carpels on its concave surface, and the limb at the summit is divided into five segments.



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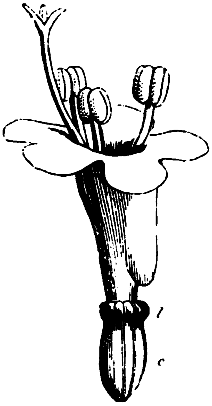

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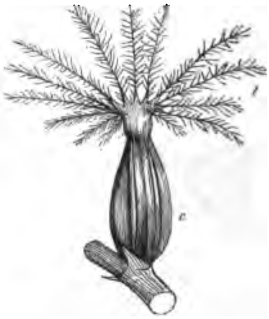


Fig. 497.

Fig. 495. Receptacle and reflexed involucre, *b*, of Dandelion (*Leontodon Taraxacum*), with the fruit and calyx, *c*, adherent to it. The limb of the calyx appears in the form of stalked hairs (pappus). The calyx is said to degenerate, so as to become pappose.

Fig. 496. Flower of Valerian (*Valeriana*), with the calyx, *c*, adherent to the fruit. The limb, *l*, of the calyx appears as a ring, composed of numerous hairs which are coiled up, from without inwards. The corolla is gamopetalous, irregular, gibbous at the base on one side. There are three stamens and one pistil.

Fig. 497. Fruit of Valerian (*Valeriana*), with adherent calyx, *c*; the limb of the calyx, *l*, has now expanded, so as to appear as feathery pappus. In Figure 496, this limb is in the form of a ring.

265. In place of being persistent, the calyx is frequently *deciduous*, falling off immediately after the flower expands, as in Crowfoot (Fig.

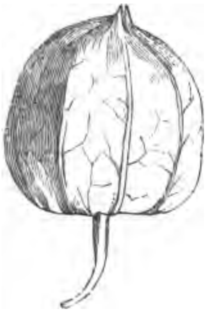
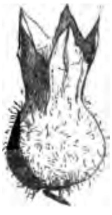


Fig. 500.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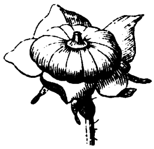
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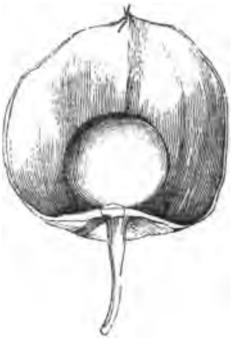
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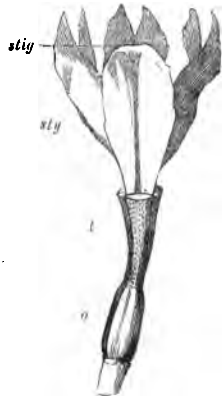

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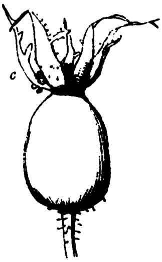
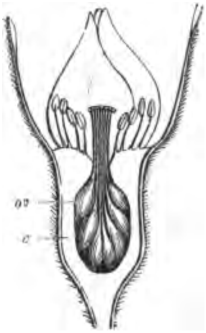


Fig. 503.



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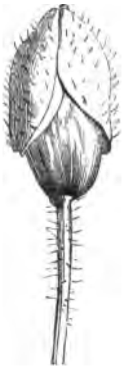


Fig. 505.

Fig. 498. Urceolate (pitcher-like) calyx of Henbane (*Hyoscyamus*), applied closely to the seed-vessel (capsule), but separable from it. The limb shows five lobes, indicating the five sepals which form the calyx.

Fig. 499. Persistent calyx of Mallow (*Malva*), remaining attached to the fruit, after the flower withers.

Fig. 500. Bladder-like calyx of the Winter Cherry (*Physalis Alkekengi*), which is persistent, or remains after the corolla and stamens have fallen.

Fig. 501. Bladder-like calyx of the Winter Cherry (*Physalis Alkekengi*), laid open to show the mode in which it surrounds the fruit without adhering to it. The calyx is persistent, but not adherent. It enlarges after the flower withers, and is called accrescent.

Fig. 502. Flower of Iris, with the upper part of the perianth cut away. The perianth is adherent to the lower portion of the pistil, *o*, and part of the tube of the perianth, *t*, is seen above the ovary, *o*. Hence, the perianth is superior, and the ovary inferior. The styles are marked *sty*, and the stigmas *stig*.

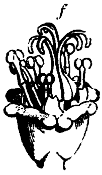
Fig. 503. Fruit of the Rose (*Rosa*), consisting of the thickened calyx bearing the carpels inside. The limb of the calyx, *c*, is divided into five segments.

Fig. 504. Fruit of the Rose cut vertically, showing the concave tube of the calyx, *c*, bearing numerous separate carpels, *ov*, with styles attached. The stamens are attached to the calyx. Some look upon the part bearing the carpels as a hollow portion of the receptacle, while others consider it as really the tube of the calyx lined with a fleshy disk.

Fig. 505. Caducous calyx of Poppy (*Papaver*). It is composed of two sepals, which fall off before the petals expand.

337, p. 144). In the Poppy (Fig. 505), the two sepals are detached before the anthesis or the opening of the flower, and they are said to be *caducous.* In Eschscholtzia, the calyx is composed of sepals united together, and joined by an articulation to the thalamus. As the flower expands, they give way at the joint, and fall off in the form of a candle-extinguisher.

266. By the irregular development of one or more sepals, the *spurred* (calcarate) calyx of Larkspur and of Indian Cress (Fig. 483, p. 196), is produced, as well as the *hooded* or helmet-shaped (galeate) calyx of Monkshood (Fig. 482, p. 195). In Grasses and Rushes the perianth assumes a glumaceous or scaly appearance. In Diplolæna, the sepals are reduced to five scales. Occasionally there is a suppression of one or more sepals, as in some species of Chenopodium and Blitum. Accidental suppressions of this kind have also been seen in the proliferous variety of Arabis alpina.



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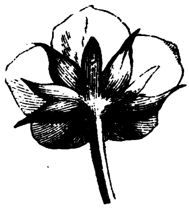

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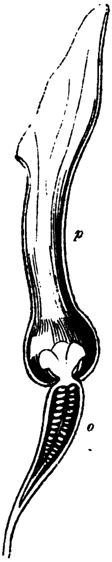

Fig. 509.

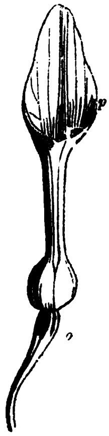

Fig. 508.

267. It is very rare to find the calyx wholly absent. This, however, occurs in some of the Euphorbias, in which the flowers are naked (achlamydeous), as shown in Figure 418, p. 175. In these

Fig. 506. Calyx-like (Calyciform) involucre of Euphorbia, enclosing numerous male flowers, and one female flower, *f*, with three forked styles. The individual flowers are really naked or achlamydeous, in consequence of the floral envelopes being suppressed.

Fig. 507. Double calyx (Calyculate calyx) of Strawberry (*Fragaria vesca*). The outer calyx is called epicalyx, and consists of five small leaves, while the inner consists of five large sepals. Some consider the epicalyx as a verticil of bracts.

Fig. 508. Flower of Birthwort (*Aristolochia*), consisting of a single floral envelope (calyx), adherent to the pistil, *o*. The flower is monochlamydeous, and the perianth, *p*, superior and irregular.

Fig. 509. Flower of Birthwort (*Aristolochia*), cut vertically, showing the single envelope (calyx) adherent to the ovary, *o*, which contains ovules. The perianth, *p* (calyx) is coloured.

plants there is a series of bracts which at first sight appear to be the calyx; but they are really an involucre inclosing several distinct flowers (Fig. 506). In the Strawberry and Potentilla, the calyx consists of two alternating whorls (Fig. 507), the exterior of which has been called *epicalyx*, and is by some considered a row of bracts. The same thing occurs in the Mallow tribe (Fig. 355, p. 150, and Fig. 356, p. 151). The nature of this epicalyx serves to distinguish some of the genera. This epicalyx is also seen in the Carnation (Fig. 404, p. 170). When there is only one floral envelope present, as in Goosefoot (Fig. 412, p. 174), and in Birthwort (Figs. 508 and 509), it belongs to the calycine whorl, whatever may be its form or colour.

B. *The Corolla or Inner Floral Envelope.*

268. The Corolla is the inner envelope of the flower, and is composed of a whorl of leaves called *petals*, which alternate with the sepals, as seen in Figure 510, and are frequently equal to them in number (isomerous), or some multiple of them. The petals differ from the sepals in being rarely green. They usually exhibit showy colours, and are often odoriferous. Structurally they are composed of cellular and vascular tissue, the latter being spiral vessels and delicate tubes. The epidermis of petals does not in general exhibit stomata, but it sometimes displays beautiful hexagonal and radiating markings under the microscope. It is usually smooth (glabrous), but occasionally coloured hairs occur on it, as in the Buckbean.

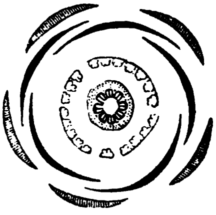

Fig. 510.

269. Petals originate in cellular projections, which are either connected by a ring of cellular tissue, or are separate, according as the parts are ultimately to be united, or to remain distinct. Even when the petals become irregular in after growth, they are equal in the first instance.* Some petals continue to increase in size after the flower has expanded. Thus, in the long-tailed Ladies'-slipper (Cypripedium caudatum), the petals are very short when the flower opens, but they acquire length day by day, at a rate which would enable an attentive observer to see them grow. Mrs. Lawrence gives the following measurements of a plant which flowered at Ealing Park:—

	Inches long.
When the flower first opened, the petals were	¾
On the second day	4½
On the third day	8½
On the fourth day	13
On the fifth day	18½

Fig. 510. Diagram of the flower of the Orange, shewing an external whorl of five sepals, and an internal one of five petals, alternating with the sepals. The third whorl is the stamens and the fourth the pistil.

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* Barneoud sur le developpment des Corolles irregulieres, Ann. des Sciences Nat. 3d Ser. Bot. viii. 344.

The same lengthening of the petals occurs in Epidendrum antenniferum, a singular orchid, from Xalapa.*

270. The forms of petals vary. Sometimes they resemble sessile coloured leaves, as in Crowfoot (Fig. 511), and in the Rose and Cinquefoil; at other times they are separated into two portions, as in the Globe-flower (Fig. 512), and Wallflower (Fig. 513), one narrow, *c*, forming the *claw*, and the other broad, *l*, constituting the limb or *lamina*. Petals being like leaves, exhibit varieties in their outline or circumscription. In some plants they are split at the apex, so as to be bifid (Fig. 514), or trifid, or cut into numerous segments (Figs. 515 and 516). When a small portion of their apex is deficient they become emarginate and obcordate (Fig. 405, p. 171), and when lobed at the base they are cordate (Fig. 535, p. 207). The apex of petals is sometimes prolonged in the form of a narrow thread, as in Strophanthus, or it ends in a point, which is either straight or inflexed as in Umbelliferous plants (Fig. 517, *p*). Sometimes petals which are bifid or fringed, such as those of the Pink and Caucalis grandiflora, become divided to their base. This division of petals has also been seen in Poppies and in Saponaria. Some petals are folded, so as to assume a tubular or pitcher-like form, as in the Hellebore (Fig. 518), a spurred form, as in Colum-

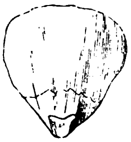
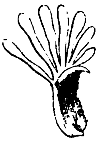


Fig. 511.



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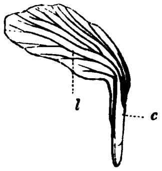

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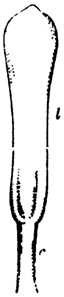

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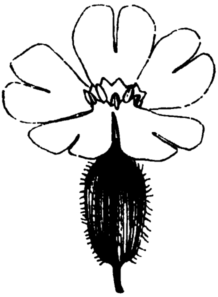

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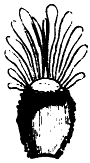

Fig. 516.

Fig. 511. Petal of Crowfoot (*Ranunculus*), without a claw, and thus resembling a sessile leaf. At the base of the petal a nectariferous scale is seen. This scale may be considered as produced by transverse chorisis or dilamination.

Fig. 512. Strap-shaped and stalked petal of Globe-flower (*Trollius europæus*); the stalk or claw is marked *c*, the blade *l*.

Fig. 513. Unguiculate or stalked petal of Wallflower (*Cheiranthus Cheiri*); *c*, the claw or unguis; *l*, the blade or lamina.

Fig. 514. Flower of Campion (*Lychnis*), with five petals, the laminæ of which are split into two, and are called bifid. Scales occur on the petals at the point where the blade and claw unite.

Fig. 515. One of the lateral petals of Mignonette (*Reseda*). Its blade is cut into numerous segments, and has been called laciniated.

Fig. 516. Inner petal of Mignonette (*Reseda*), shewing a blade divided deeply into numerous segments. The division or laciniation of the petals is common in the natural order Resedaceæ.

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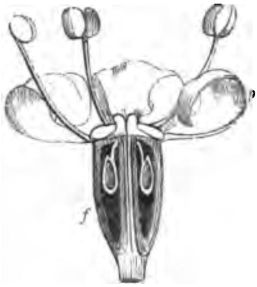
* See Paxton's Flower Garden, February and May 1850.

bine (Fig. 519), Violet (Fig. 520), and Larkspur (Fig. 521), a gibbous form, as in Fumitory (Fig. 522), or a horn-like aspect, as in the petals



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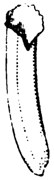

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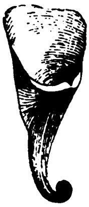

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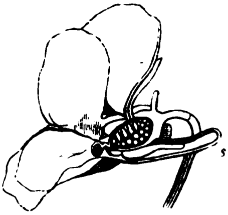

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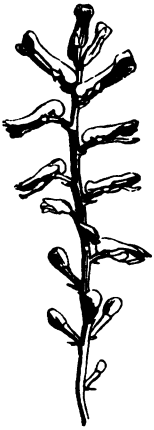

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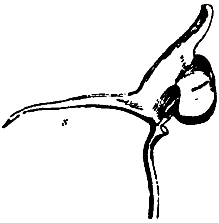

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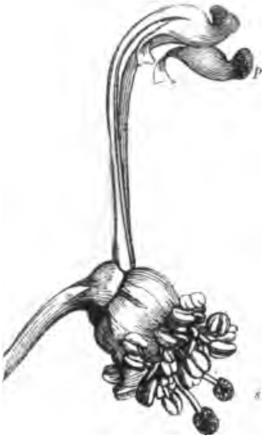


Fig. 523.

Fig. 517. Flower of Fennel (*Fœniculum vulgare*), an umbelliferous plant, cut vertically. The petals, *p*, are shewn with inflexed points (apicula). The calyx is adherent to the fruit, *f*, which is opened, so as to exhibit two achænia, with a single pendulous ovule in each. At the apex of the fruit, and in the centre of the flower, there are two styles and stigmas, with an enlargement at their base, called an epigynous disk. The stamens are united to the calyx.

Fig. 518. Tubular petal of Hellebore (*Helleborus*), formed by folding and adhesion, in the same manner as pitchers (Par. 199). These hollow petals were called nectaries by Linnæus.

Fig. 519. Horn-like hollow petal of Columbine (*Aquilegia vulgaris*), formed by folding and adhesion of the edges.

Fig. 520. Section of flower of Violet (*Viola*), shewing one of the petals with a long hollow spur, *s*. The petal is said to be spurred or calcarate. The ovary is laid open to show the ovules, and the spur is split open to show a staminal process extending into it.

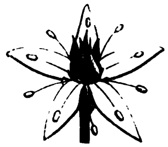
Fig. 521. Spurred (calcarate) petal of Larkspur (*Delphinium*). The long process, *s*, extends into a hollow spur of the coloured calyx.

Fig. 522. Racemose flowers of Fumitory (*Fumaria officinalis*), exhibiting gibbous swellings at their base. In Fumitories one of the petals is gibbous, while in some other genera of the order two of them are in this state. Such corollas are said to be saccate at the base. Small bractlets are seen at the point where the pedicels join the rachis or general peduncle.

Fig. 523. Two peculiar horn-like stalked petals, *p*, of Monkshood (*Aconitum Napellus*). They are situated under the helmet-shaped (galeate) coloured sepal, and they consist of a grooved stalk supporting a hollow spurred petal. These anomalous petals were called nectaries by Linnæus Below the petals in the Figure are seen numerous stamens, *s*, attached to the receptacle.

under the helmet-shaped sepals of Monkshood (Figs. 523, *p*, and 482, p. 195). These anomalous petals sometimes assume a normal form, as in a variety of Columbine, in which the spurs disappear (Fig. 524).

271. When the petals are separate (free and distinct) the corolla is *Polypetalous* or *Dialypetalous* (Fig. 525), and the number of the petals is indicated by prefixing the Greek numerals to the term *petalous*, in the same way as in the case of the sepals (¶ 260, p. 196). Thus, in Figure 525, the corolla is *pentapetalous*, and in Figure 526, it is *tetrapetalous*. In the Vine (Fig. 527), in which the corolla is polypetalous, the petals in their early state are united together by their apices, and afterwards separate and fall off. When the petals are united, the corolla is *Gamopetalous* or *Monopetalous* (Fig. 528), and the number of its parts is marked by the venation, or by the divisions of the apex, just as in the case of the calyx (¶ 261). Thus, in Figure 528, the corolla consists of five petals united, their number being ascertained by the lobes at the apex, as well as by the midribs. The united portion is called the *tube* (Fig. 528, *t*), the divisions are called *lobes*, *l*, and the orifice is the *throat* (faux). The term *limb* is often given to the expanded and free part of a gamopetalous corolla.



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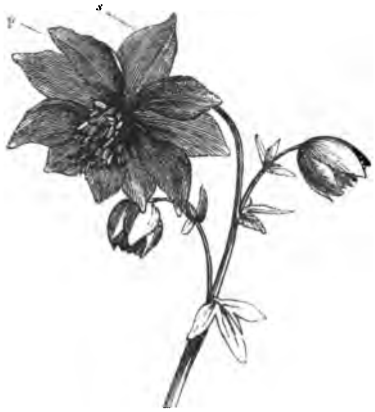

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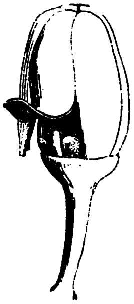

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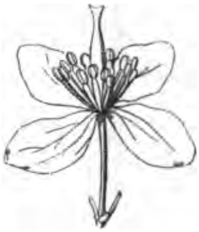


Fig. 526.

Fig. 524. Flowers of Columbine (*Aquilegia vulgaris*), in which the petals have become spurless. The ordinary petal is seen in Figure 519. The coloured sepals are five, and are marked, *s*; they alternate with the five petals marked, *p*. The inflorescence is definite, the terminal flower expanding first.

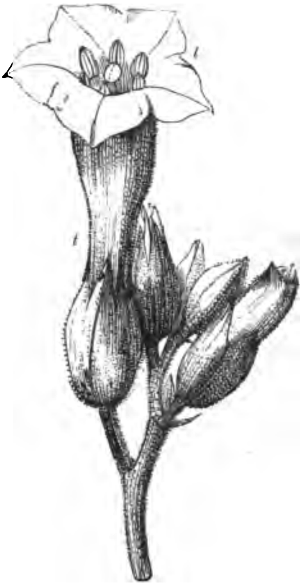
Fig. 525. Polypetalous or Dialypetalous corolla of Biting Stonecrop (*Sedum acre*). It is composed of five separate petals, and hence is pentapetalous. There are ten stamens in two rows, and five carpels.

Fig. 526. Tetrapetalous corolla of Celandine (*Chelidonium majus*). It is composed of four separate petals. The term dialypetalous means separation of petals, and hence it is applied to all polypetalous corollas. In the Figure are seen numerous stamens, in many rows, surrounding the pod-like pistil in the centre.

Fig. 527. The flower of the Vine (*Vitis vinifera*), in the young state, shewing the union of the petals at their upper part, and the mode in which they separate before they fall off.

272. Some varieties of polypetalous corollas deserve notice. Of the *regular* forms may be mentioned the *rosaceous*, as in the Rose, Rock-rose (Fig. 529), and the Strawberry (Fig. 530), in which there are spreading petals, without claws or with very short claws; the *liliaceous*, where the petals gradually taper from the apex to the base, as in the Lily (Fig. 531); *caryophyllaceous*, where the petals have long, narrow, tapering claws (Fig. 532), enclosed in the calyx, as in the Carnation (Fig. 404, p. 170), Pink, and Catchfly; *cruciferous* or *cruciate*, in which there are four petals, usually with claws (Fig. 513, p. 202), and arranged in the form of a cross, as in common Stock (Fig. 460, p. 190, and Wallflower (Fig. 479, p. 194).

273. Among the *irregular* forms of polypetalous corollas, the following deserves attention :—The *papilionaceous* (butterfly-shaped) corolla, as seen in the Pea (Fig. 297, p. 128, and Fig. 452, p. 187), in various kinds of Broom (Fig. 533), and in the Judas-tree (Fig. 534), consisting of five parts, differing in size and shape, the upper (Fig. 535), called the *standard* (vexillum), the lower (Fig. 536), called the



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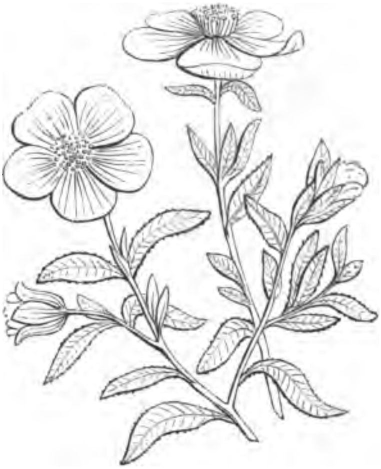


Fig. 529.

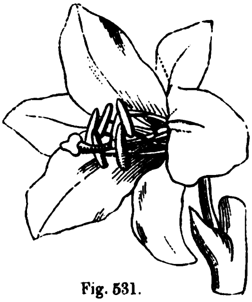
Fig. 528. Fascicled Cyme of Tobacco (*Nicotiana Tabacum*), shewing an expanded funnel-shaped (infundibuliform) flower, surrounded by the calyx at the base. There are two parts of the corolla; the tube, *t*, formed by the united claws of the petals, and the five-lobed limb, *l*, formed by the union of the laminæ.

Fig. 529. Flower of a species of Rock-rose (*Cistus creticus*), shewing a polypetalous rosaceous corolla, composed of five petals like those of the rose, having no claws. The Hebrew word *Lot*, which has been translated Myrrh in Gen. xxxvii. 25, and xliii. 11, is supposed to mean Ladanum, which is an odoriferous resin procured from this plant

keel (carina), formed of two partially-united petals, and the two lateral (Fig. 537), called *wings* (alæ).

274. In Monocotyledonous plants the coloured perianths are often polyphyllous, and there is a peculiar irregular kind which is met with among Orchids. It may be called the Orchideous perianth, and consists of six parts, one of which, called the *labellum*, presents many remarkable forms. It is shewn in Figures 538 and 539, the former of which represents an Orchis, with its labellum, *l*, and a spur, *s*, and the latter the flower of Twayblade, with a large bifid labellum, *l*. The labellum varies much in form. In Cypripedium it is hollowed like a slipper, and is called *calceolate*.

275. Gamopetalous corollas are also divided into *regular* and *irregular* forms. In the former the parts are equal in size, and equally united, while in the latter they are unequal in these respects. Regular forms are *bell-shaped* (campanulate), that is, shaped like a bell, and swelling out regularly from base to apex, as in the Hare-bell



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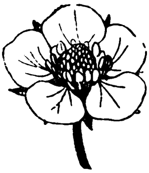

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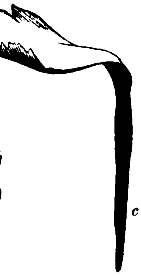

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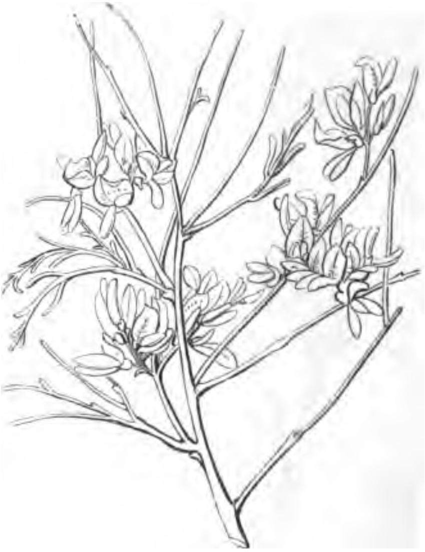


Fig. 533.

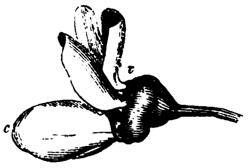
Fig. 530. Rosaceous corolla of the Strawberry (*Fragaria vesca*), composed of five petals without claws. The points of the calyx are seen alternating with the white petals.

Fig. 531. Flower of Lily (*Lilium album*), composed of six coloured pieces, in two rows. The outer row may be called the calyx, the inner the corolla. The latter consists of three leaves (petals), which taper gradually towards the base, and the corolla is called liliaceous.

Fig. 532. Petal of the Carnation (*Dianthus caryophyllus*), with a long narrow tapering claw, *c*; a corolla having petals of this kind is called caryophyllaceous.

Fig. 533. Flowering branch of a kind of Broom (*Genista monosperma*), shewing papilionaceous flowers like those of the pea. The plant has wand-like branches, and a few linear leaves, and is the *Rothem* or *Rotem* of the Old Testament, translated Juniper (1 Kings xix. 4, 5; Job xxx. 4; Psalm cxx. 4).

(Fig. 540); *funnel-shaped* (infundibuliform), in which the tube is narrow below, and expands towards the summit, as in Tobacco (Fig. 541); *tubular*, or nearly uniformly cylindrical, as in some composite flowers (Figs. 542 and 543); *salver-shaped* (hypocrateriform), when



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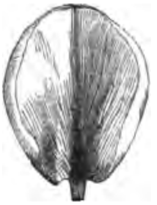

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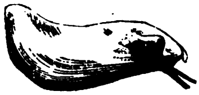

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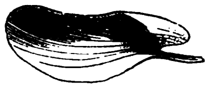

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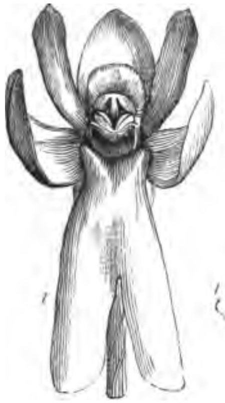

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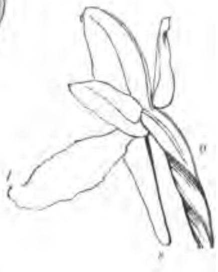

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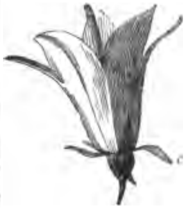

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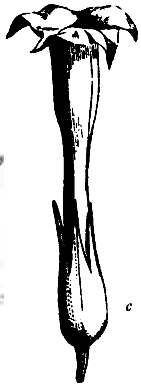


Fig. 541.

the limb or lobed portion spreads out at right angles to the tube, which is long, as in Auricula and Primrose; and *wheel-shaped* (rotate), when

Fig. 534. Papilionaceous flower of the Judas-tree (*Cercis Siliquastrum*), with the vexillum, *v*, situated within the two alæ (lateral petals) in place of enclosing them. The keel, *c*, is formed of two petals.

Fig. 535. The Standard (vexillum), or upper petal of the papilionaceous flower of Broom (*Sarothamnus scoparius*). It is cordate at the base. The alæ are overlapped by it in the bud, or, in other words, the æstivation is vexillary.

Fig. 536. Keel (carina) of the papilionaceous flower of the Broom, composed of two petals united partially, in a boat-like manner, and having two thread-like stalks at the base.

Fig. 537. One of the wings (alæ) of the papilionaceous flower of the Broom. It has a projecting portion at the base, and a narrow thread-like stalk.

Fig. 538. Irregular polyphyllous spurred perianth of Orchis. It consists of six parts, one of which, *l*, called the labellum, differs much from the rest, and gives a peculiar character to the flower. A spur, *s*, extends backwards from the labellum. The ovary, *o*, is inferior, *i.e.*, below the divisions of the perianth.

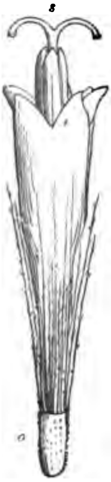
Fig. 539. Flower of Twayblade (*Listera ovata*), seen in front, shewing a large bifid labellum, *l*, which is different from the other five divisions of the perianth. The divisions of the perianth are in two rows of three each. The essential organs of reproduction are placed on a column opposite the labellum. The perianth is irregular polyphyllous, and is denominated Orchideous.

Fig. 540. Regular gamopetalous bell-shaped (campanulate) corolla of Harebell (*Campanula rotundifolia*). It is composed of five petals united. The ovary is inferior, and is united to the calyx, *c*.

Fig. 541. Regular gamopetalous funnel-shaped (infundibuliform), corolla of Tobacco (*Nicotiana Tabacum*). It is composed of five petals united. The calyx, *c*, below, consists of five sepals united.

a salver-shaped corolla has a very short tube, as in Forget-me-not (Figs. 544 and 545). There are also intermediate forms, as in Comfrey (Fig. 546), in which the corolla is campanulately-tubular, presenting a combination of the bell-shaped and tubular forms.

276. Irregular gamopetalous corollas, are seen in the *lipped* (labiate and bilabiate) forms, in which the union of the petals takes place in such a way as to produce an upper and lower portion, with a gap (hiatus) between them, like the mouth of an animal (Figs. 547 and 548). The upper lip is usually composed of two petals, the lower of three. The same form is met with in the calyx (Fig. 489, p. 197), but the number of parts in the lips is reversed. A labiate corolla



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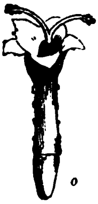

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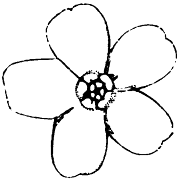

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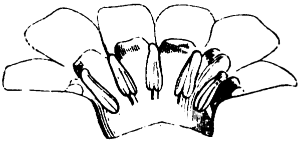

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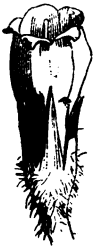

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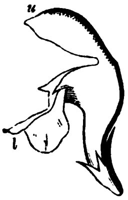

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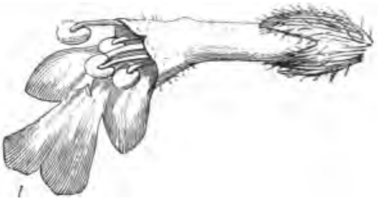


Fig. 548.

Fig. 542. Regular gamopetalous tubular corolla of one of the flowers of Ragwort (*Senecio*). The single-seeded ovary, *o*, is united to the tube of the calyx, while the limb of the latter is seen above the ovary in the form of hairs (pappus) surrounding the corolla. In the centre of the flower above are seen the stamens united into a tube, through which the style passes before it ends in a bifid stigma, *s*.

Fig. 543. Tubular gamopetalous corolla of one of the flowers of Milfoil (*Achillæa*), with the inferior ovary, *o*, and the obsolete limb of the calyx.

Fig. 544. Regular gamopetalous wheel-shaped (rotate) corolla of Forget-me-not (*Myosotis*), consisting of five petals united, with a very short tube. Scales are seen at the throat.

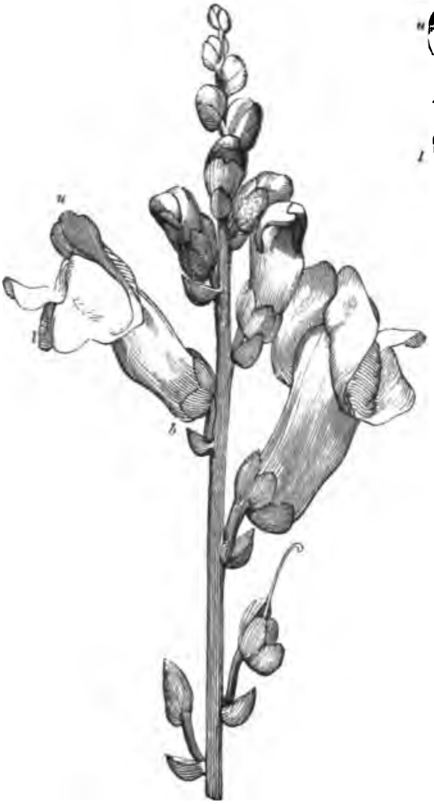
Fig. 545. The wheel-shaped corolla of Forget-me-not (*Myosotis*) laid open to show the short tube, the five stamens attached to the corolla, and the five scales on the petals alternating with the stamens.

Fig. 546. Campanulate tubular corolla of Comfrey (*Symphytum*). It may be considered as combining the bell-shaped and the tubular forms of gamopetalous corolla. It is composed of five petals united, and is surrounded by a five-partite calyx at the base.

Fig. 547. Irregular gamopetalous labiate corolla of the Dead-nettle (*Lamium album*). The upper lip, *u*, is composed of two petals united, the lower lip, *l*, of three. Between the two lips (labia) there is a gap (hiatus). The throat is the part where the tube and the labiate limb join. From the arching of the upper lip this corolla is called ringent.

Fig. 548. Irregular gamopetalous labiate corolla of Bugle (*Ajuga reptans*). In this plant the upper lip is nearly awanting, and the stamens are seen, two long and two short, projecting beyond the tube. The lower lip, *l*, is formed of three parts, and is said to be three-lobed.

or calyx, with the upper lip much arched, like a helmet (galea), is said to be *ringent* (Fig. 547). Sometimes the upper lip is very short



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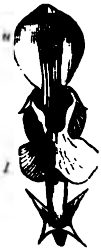

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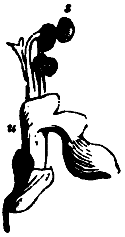

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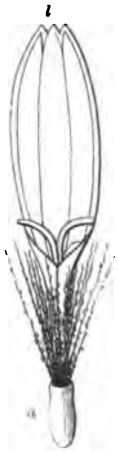

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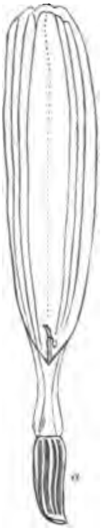


Fig. 553.

Fig. 549. The labiate corolla of the white Dead nettle (*Lamium album*), seen in front, shewing the two lips, *u* and *l*, the gap and throat, as well as the didynamous stamens. The calyx below is also irregular, three parts forming a sort of upper lip, and two forming a lower.

Fig. 550. Irregular gamopetalous labiate flower of Germander (*Teucrium*), seen in profile. The upper lip, *u*, is short, and the stamens, *s*, are much exserted beyond it, the lower lip, *l*, is patent (spreading), and three-cleft.

Fig. 551. Flowering raceme of Frogsmouth (*Antirrhinum majus*). The flowers have irregular gamopetalous personate corollas, the lower lip, *l*, with its three parts being pushed upwards on the dimerous upper lip, *u*, so as to leave only a chink between them. The convex projecting portion of the lower lip is called the palate, which is frequently coloured differently from the rest of the corolla. The corolla is also gibbous (saccate) at the base, *b*, on one side.

Fig. 552. Irregular gamopetalous ligulate flower of Ragwort (*Senecio*). It is a tubular floret, split down on one side, with the united petals forming a strap-like projection, *l*. The lines on the flat portion indicate the divisions of the five petals. From the tubular portion below, the bifid style projects slightly. The terete fruit (achænium), *a*, is surmounted by pilose pappus, which is the metamorphosed calycine limb. The flower is female, having no stamens.

Fig. 553. Ligulate flower of Ox-eye (*Chrysanthemum*). It is a tubular floret split down on one side. The fruit, *a*, is adherent to the tube of the calyx, and the calycine limb is obsolete. There is no pappus. The flower is pistilliferous.

and nearly awanting, as in Bugle (Fig. 548), and in Teucrium (Fig. 550, *u*). When the lower lip is approximated to the upper, so as to leave only a chink (rictus), with a projecting portion below it, called the palate, the corolla is denominated *masked* (personate), as seen in Frogsmouth (Fig. 551). In Calceolaria there is a peculiar irregular corolla with two hollow lips. When a tubular corolla is split down on one side (Figs. 552, 553, and 554), as in the white florets of the Daisy, it is called *strap-shaped* (ligulate). This kind of corolla is well seen in composite flowers, such as the Dandelion (Fig. 361, p. 153), in which all the flowers forming the head are ligulate, and the Marygold (Fig. 371, p. 156), in which the outer flowers forming the ray are ligulate, while the central are tubular.

277. The lower part of some gamopetalous corollas, such as Valerian (Fig. 496, p. 198) and Frogsmouth (Fig. 555, *b*), projects in the form of a bag or sac, and is called saccate or gibbous. Sometimes the projecting part assumes the form of a spur (calcar), as in Red Valerian (Fig. 556, *c*), and Snap-dragon (Fig. 557, *c*). In some gamopetalous corollas there is a very slight irregularity of form. Thus, in Digitalis (Fig. 558), the corolla has a somewhat campanulate form, but its development is not equal; the Speedwell (Fig. 559) has a form nearly rotate, but the lobes are unequal; the Bugloss (Fig. 560) has a funnel-shaped corolla with a curved tube. In some gamopetalous corollas with a single spur, it happens occasionally, that what are called Pelorian varieties occur in which five spurs are produced. This occurs in common Snap-dragon frequently, as well as in species of Frogsmouth.

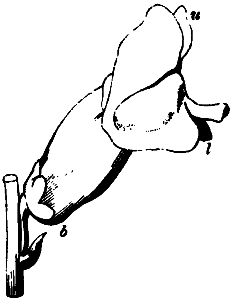
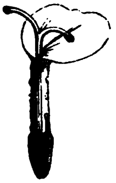


Fig. 555.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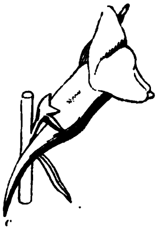


Fig. 557.

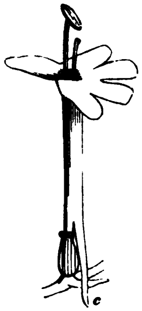


Fig. 556.

Fig. 554. Ligulate flower of Milfoil (*Achillæa*), with the forked style projecting beyond the tube. There is no pappus. The flower is pistilliferous (female).

Fig. 555. Personate corolla of Frogsmouth (*Antirrhinum majus*), shewing the gibbous base, *b*, of the corolla. The lower lip, *l*, is pushed up on the upper, *u*, leaving a chink (rictus).

Fig. 556. Irregular gamopetalous flower of Red Valerian (*Centranthus ruber*), shewing the projecting spur, *c*, at the base. A stamen and a style are seen projecting beyond the flower above. The flower is monandrous and monogynous. The corolla consists of five united petals, the calyx limb forms a ring at the top of the ovary, and it finally becomes a feathery pappus crowning the fruit.

Fig. 557. Irregular gamopetalous personate flower of Snap-dragon (*Linaria*), with a long spur, *c*, (calcar) at the base. The corolla is denominated spurred or calcarate.

278. In Grasses and Sedges the arrangement of the parts of the flower is peculiar. In place of verticillate leaves forming the flower, there are alternate scales or glumes. The flowers of grasses usually occur in spikelets (Fig. 561), which consist of one or two glumes, *a*, covering several flowers, *b*. In Wheat (Fig. 384, p. 160), these spikelets are arranged alternately along a common rachis. Each spikelet consists of two glumes, having the form represented in Figure 562, and enclosing flowers which are composed of scales (paleæ or glumellæ), delineated in Figures 563 and 564—the former being the outer, and, the latter the inner pale or glumella—which are placed at different heights in an alternate manner. In the flower of the Oat (Fig. 565),

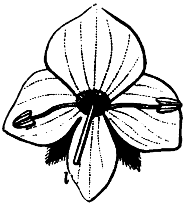
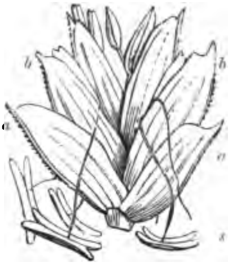


Fig. 559.



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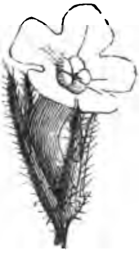
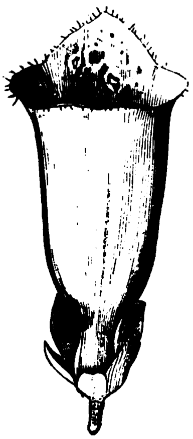


Fig. 560.



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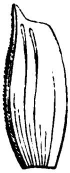


Fig. 562.

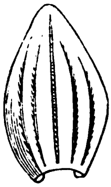


Fig. 563.

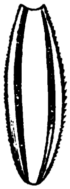


Fig. 564.

Fig. 558. Irregular gamopetalous somewhat bell-shaped corolla of Fox-glove (*Digitalis purpurea*). The limb of the corolla is oblique, and there is a short tube below. The corolla has sometimes been called Digitaliform.

Fig. 559. Irregular gamopetalous wheel-like corolla of Speedwell (*Veronica*). The irregularity consists in the different sizes of the lobes of the corolla, especially the lower lobe, *l*, which is much smaller than the rest. There is an approach to a lipped corolla. The stamens are two, and the style one, so that the flower is Diandrous and Monogynous.

Fig. 560. Gamopetalous corolla of Bugloss (*Lycopsis arvensis*), with a curved tube. The corolla is somewhat funnel-shaped, with its mouth closed by connivent convex scales, its limb being five-lobed. The calyx is five-partite.

Fig. 561. A spikelet of Wheat (*Triticum*), consisting of two glumes, *a a*, enclosing several flowers, *b b*, which are composed of two pales (paleæ) covering the essential organs of reproduction. The stamens, *s*, hang out by long slender thread-like filaments. The individual glumes and paleæ are placed alternately on the floral axis.

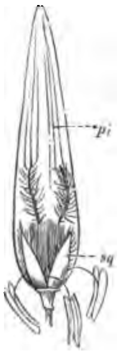
Fig. 562. One of the glumes of Wheat (*Triticum*), seen in profile. These glumes are bracts or floral leaves which constitute the outer covering of the spikelet. They are placed at different levels, following the law of alternation. The glume is marked with three ribs.

Fig. 563. External (outer) palea or glumella of the flower of Wheat. It is a glumaceous scale marked with two ribs on each side of the midrib.

Fig. 564. Internal (inner) palea or glumella of the flower of Wheat. It is thinner and more membranous than the outer glumella, its edges are folded inwards, and its apex is bifid.

after removing the outer pale or glumella, the inner one, *pi*, is seen with two scales (lodiculæ or squamæ), *sq*, at the base, enclosing the essential organs of reproduction. In Carices the male flowers are borne on scales, and so are the female, as shown in Figure 566, in which the scale, *s*, is placed on one side. Within the scale the female flower is situated, having a peculiar bag-like covering, *u*, termed perigynium.

279. *Abnormalities in the Corolline Whorl.*—The parts of the corolla are frequently adherent to those of the calyx, and any change taking place in the latter also causes an alteration in the former. Petals are sometimes suppressed. Thus, Seringe describes a flower of Diplotaxis tenuifolia, with two petals suppressed. The flower of the Haricot has been noticed wanting the carina, and in the blossom of a Pea, Moquin observed the disappearance of all the parts except the standard. Sometimes the entire corolla is wanting. This occurs normally in apetalous monochlamydeous flowers, such as Chenopodium (Fig. 412, p. 174). It also occurs accidentally. Linnæus mentions the absence of the corolla in Campanula perfoliata, and Ruellia clandestina. The same



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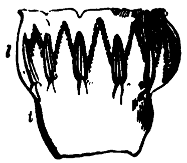


Fig. 567.

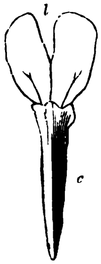


Fig. 568.

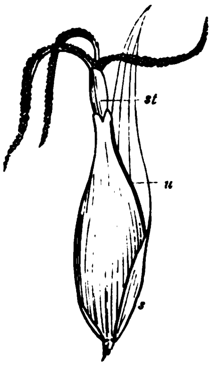


Fig. 566.

Fig. 565. Flower of Oat (*Avena sativa*), with the two glumes, and the outer glumella or palea removed. The inner glumella or palea, *pi*, is seen, of a lanceolate form, and bidentate at the apex. The outer glumella has a long twisted geniculate dorsal awn, with two points or bristles at the summit. By removing this glumella there are seen two scales (lodiculæ, squamæ), *sq*, with the three stamens and two feathery styles.

Fig. 566. Female (pistilliferous or pistillate) flower of a Sedge (*Carex*), with a single glume or scale, *s*. The pistil is covered by an urceolate glumaceous bag, *u*, called perigynium. There is one style, *st*, with three stigmas at its summit.

Fig. 567. Regular gamopetalous corolla of Comfrey (*Symphytum*), laid open, shewing the tube, *t*, and the limb, *l*. At the part where the tube and limb unite, the five stamens are placed, attached to the corolla (epicorolline). Between the stamens, and alternating with them, are five coloured scales, which, being opposite the lobes of the corolline limb, are supposed to be formed by transverse chorisis or dilamination. These scales were called nectaries by Linnæus. They are looked upon as modifications of the petals.

Fig. 568. Unguiculate (clawed) petal of Campion (*Lychnis*), with a bifid lamina, *l*, and a scale at the part where the claw, *c*, and lamina unite. This coloured scale is supposed to be produced by transverse chorisis from the petal. It was called nectary by Linnæus.

abnormality has been observed in the March-Violet, and other species of Viola, in Chickweed, Jacob's-ladder, Teucrium Botrys, Lamium amplexicaule, Rosa centifolia, and Melilotus officinalis. In Amorpha and Afzelia the corolla is reduced to a single petal, and in some other leguminous plants it is entirely awanting. In the natural order Ranunculaceæ, some genera, such as Ranunculus, Globe-flower, and Pæony, have both calyx and corolla, while others, such as Clematis, Anemone, and Caltha, have only a coloured calyx; and in a third set, such as Hellebore, Aconite, and Larkspur, the petals assume remarkably abnormal forms.

280. Petals, which are in general coloured, sometimes become green. This has been observed in the flowers of Fraxinella, of Rampion, and of several species of Shepherd's Club. A corolla, normally gamopetalous, is sometimes divided into separate petals. The flower of Cobæa scandens has been observed divided into five petals, and the corollas of Campanula media and of Rhodora canadensis are occasionally deeply divided.

281. Flowers become double by the multiplication of the parts of the corolline whorl. This arises in general from a metamorphosis of the stamens. It is very common in the natural orders Ranunculaceæ, Papaveraceæ, Magnoliaceæ, Malvaceæ, and Rosaceæ; whilst it is rare in Leguminosæ. The tendency to produce double flowers is sometimes very strong; thus Kerria japonica in cultivation is never seen except with double flowers.

282. Union of separate flowers (synanthos) occasionally occurs, and the adhesion which thus takes place causes various changes in the whorls. Flowers may be united by their peduncles, as seen in some anomalous specimens of Dandelion, Hyacinth, and Centaury; or by their outer parts, such as the calyx. At other times there is a complete fusion, as it were, of all the parts of the flowers, some continuing normal, others being suppressed or abortive. It is rare to find the number of parts exactly double that of the flower in the cases when two flowers are joined, or triple when three are united. Martins noticed the union of two flowers of Petunia violacea, in which, in place of ten parts, there were eight sepals, eight divisions of the corolla, and eight stamens. Jussieu gives instances of synanthos in the Periwinkle with the parts varying in number from six to eight. Flowers of Frogsmouth have been seen with seven lobes of the corolla, and seven fertile stamens; also with eight divisions of the calyx, eleven lobes of the corolla, and eight stamens. The union of three flowers of Lilac has produced a flower with eleven lobes of the corolla, and three pistils. Examples of synanthos are common in species of Ranunculus, Aconite, Digitalis. In the latter we often find three or more flowers united at the apex of the raceme, and expanding before the others; thus exhibiting an instance of definite, in place of indefinite, expansion.

283. Connected with the inner surface of the petals, there are

placed occasionally appendages in the form of scales or filamentous processes. These are considered as being modified petals, and they are usually traced to transverse chorisis, in consequence of their being placed opposite to the petals. In many of the Borage order, such as the Comfrey (Fig. 567), Forget-me-not (Figs. 544 and 545, p. 208), Bugloss (Fig. 560, p. 211), and Hound's-tongue, as well as in the Chickweed tribe (Fig. 514, p. 202, and Fig. 568), and in the Crowfoot (Fig. 511, p. 202), petaline scales or lamellæ of this nature are observed, which, like many other processes connected with the flower, received, in the days of Linnæus, the name of Nectaries. Peculiar changes in an inner row of petals and in the stamens may also give rise to corolline appendages, as, for instance, in the beautiful fringes of the Passion-flower, in the crown of the Narcissus (Fig. 343, p. 147, and Fig. 569, *n*), and in the glandular scales of the grass of Parnassus (Fig. 570).

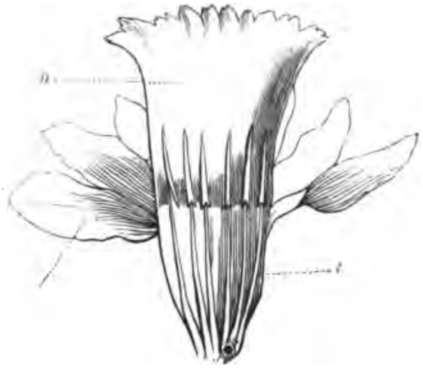


Fig. 569.

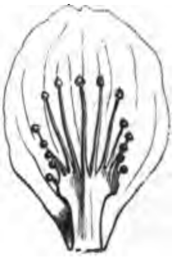


Fig. 570.

284. General recapitulation of facts relative to the floral envelopes:—

1. The floral envelopes consist of the calyx and corolla—in other words, the calycine and corolline whorls, the parts of which alternate with each other.
2. When one of these only is present, it is the calyx, and hence such a flower is apetalous, or has no corolla.
3. When both envelopes are present, the flower is dichlamydeous; when one only is developed, monochlamydeous; when none, achlamydeous.
4. When the floral envelopes are in one whorl, or when both whorls are alike, as in many monocotyledons, the terms perianth and perigone are applied.

Fig. 569. Flower of Daffodil (*Narcissus Pseudo-narcissus*), laid open. The flower consists of a gamophyllous double coloured perianth, composed of six pieces, *l*. The tube of the perianth, *t*, bears the six stamens in two rows. From the tube there is produced a bell-shaped crown (corona), *n*, which has been called a nectary. It is supposed to be either a modification of the perianth, produced by transverse chorisis, or of the stamens.

Fig. 570. Petal of the grass of Parnassus (*Parnassia palustris*), bearing a remarkable fringed glandular scale, which may be considered as a modified petal, produced by transverse chorisis, or as an altered condition of the stamens. It has received the name of nectary.

5. **The calyx consists of sepals which are separate in a polysepalous calyx, and united in a gamosepalous one.**
6. **The corolla consists of petals which are separate in a polypetalous corolla, and united in a gamopetalous one.**
7. **The sepals and petals follow the same law of development as the leaves, to which they are allied also in structure and form. They are arranged either in verticils or in spiral cycles having scarcely any internodes.**
8. **Irregularities in the calyx and corolla are caused by suppression or total absence of parts; by degeneration, so that the parts appear in the form of scales, hairs, or a mere rim; by abnormal development of parts in the form of spurs, foldings, and hollow tubes; by adhesion, in an irregular manner; by multiplication, or increase in number; and by chorisis, or splitting of parts.**

4. ESSENTIAL REPRODUCTIVE ORGANS.

285. These organs constitute the inner whorls (verticils), and originate, like the floral envelopes, from the thalamus or torus (the upper part of the axis or peduncle), in the form of minute cellular processes. In their development they resemble leaves, but in general they differ much more in their appearance from the leaves than the floral envelopes do. The essential organs are the stamens and pistil, as shewn in Figure 571, where there are five stamens arising from the thalamus, and surrounding one pistil. The stamens constitute the *Andrœcium*, and the pistil the *Gynœcium*.

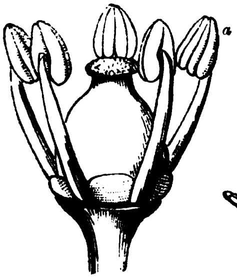
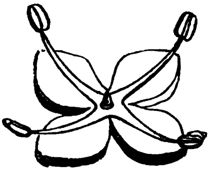


Fig. 571.



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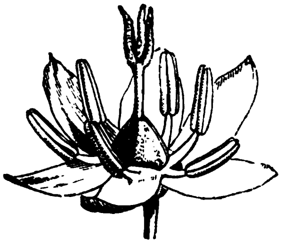


Fig. 572.

286. These organs are necessary to form a perfect flower, and

Fig. 571. Andrœcium and Gynœcium, or, in other words, the essential organs (stamens and pistil) of the Vine (*Vitis vinifera*). There are five stamens, with introrse two-lobed anthers, *a*. The division between the anther-lobes is narrow, and corresponds to the midrib of the leaf. On the face of each lobe of the anther is seen the suture or line of dehiscence. The anthers are inserted into the thalamus (receptacle). Between the anthers at their base are scales forming the disk. These scales are probably abortive stamens. The ovary is large, style short, and stigma undivided.

Fig. 572. Flower of Wood-rush (*Luzula*), shewing six divisions of a glumaceous perianth (perigone), in two rows of three each; six stamens, with two-lobed introrse anthers, arranged in two rows alternately. The line in the middle of the anther shews the connective, and some of the lobes shew also the line of dehiscence (suture). The filaments become broader below. In the centre is the pistil with ovary, style, and three stigmas at the apex.

Fig. 573. Staminate, staminiferous, or male flower of Mulberry (*Morus nigra*), shewing a four-partite calyx, and four stamens, with long filaments, and two-lobed anthers. The flower is monochlamydeous, from absence of the corolla, and the stamens are opposite the segments of the perianth on account of the suppression of the corolline whorl.

without them no seed is produced in flowering plants. When, by cultivation, they are changed into floral envelopes, the flower cannot

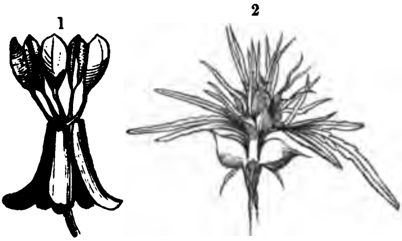
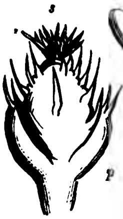


Fig. 574.



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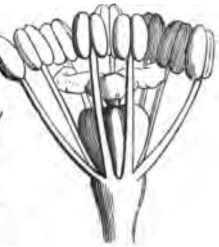

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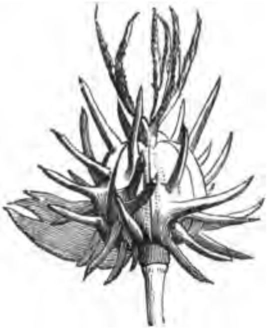

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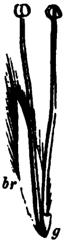

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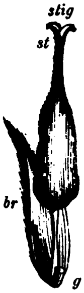

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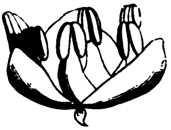

Fig. 580.

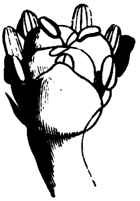

Fig. 581.

Fig. 574. Flowers of Hemp (*Cannabis sativa*), (1) staminiferous flower shewing reflexed perianth (calyx), and five innate (erect) stamens, with short filaments; (2) cluster of pistilliferous, or pistillate flowers, enclosed by bracts, each flower having a perigone split at the side, one ovary, and two pubescent styles.

Fig. 575. Pistilliferous or female flower of the Nettle (*Urtica*), consisting of a two-leaved perigone, *p*, with a single pistil. The Pistil consists of an ovary, and a sessile penicillate stigma, *s*.

Fig. 576. Pistillate flower of the Castor-oil plant (*Ricinus communis*), shewing one of the leaves of the perianth, with the bristly ovary in the centre, consisting of three uni-ovular carpels united. The fruit is called tricoccous, being formed of three cocci or single-celled carpels, which separate from each other in an elastic manner when ripe.

Fig. 577. Essential organs of Rhubarb (*Rheum*), shewing nine stamens, inserted on the thalamus (hypogynous), and the pistil in the centre. The filaments are long, and anthers two-lobed. The stigma is divided into three disk-like parts.

Fig. 578. Staminiferous flower of the Willow (*Salix*), shewing the bract, *br*, the two stamens, with a gland, *g*, at the base. The flower is diandrous.

Fig. 579. Pistilliferous flower of the Willow (*Salix*), shewing the bract, *br*, the stalked ovary, with style, *st*, and bifid stigma, *stig*, and a gland at the base, *g*. The flower is monogynous, having a single pistil. The Willow is diœcious, inasmuch as the male and female flowers are on separate plants.

Fig. 580. Male (staminiferous) flower of a Palm (*Chamærops*), shewing three divisions of the perianth, and six stamens in two rows. The two lobes of the anther are seen separated by the connective.

Fig. 581. Hermaphrodite flower of a Palm (*Chamærops*), shewing the perigone enclosing six stamens surrounding a three-celled pistil. The Palm is polygamous, having male, female, and hermaphrodite flowers

perform its proper functions. These organs are not, however, always present in every flower. When both are present in the same flower, it is *bisexual*, *hermaphrodite*, or *monoclinous* (Figs. 571 and 572), and is marked ☿. When one of the organs only is present, the flower is *unisexual* or *diclinous*, and is marked ♂ ♀; being called *staminate*, male or sterile, when the stamens alone are developed (Figs. 573 and 574, 1), as indicated by the mark ♂; and *pistillate*, female or fertile, when the pistil only is produced (Figs. 575 and 576), as indicated by the mark ♀.

287. It is necessary that there should be some communication between the stamens and pistil, so that the pollen or fertilizing powder prepared by the former should be applied to the latter, which contains the rudiments of the seed. In the case of hermaphrodite flowers (Fig. 577) this is readily accomplished, as the two organs are close to each other. In the case of unisexual flowers, in which the staminiferous and pistilliferous flowers are on the same plant, and hence denominated *monœcious* (♂ ♀), such as the Hazel (Fig. 582), Oak

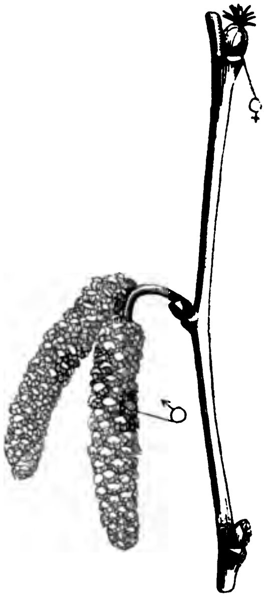

Fig. 582.

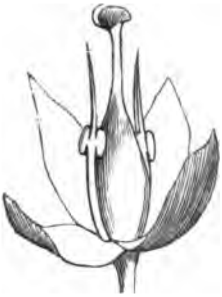

Fig. 584.

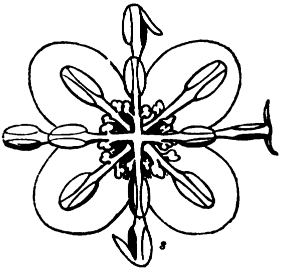

Fig. 583.

Fig. 582. Flowering branch of Hazel (*Corylus Avellana*), shewing catkins of male flowers, ♂, and female flowers, ♀. The tree is monœcious, having staminiferous and pistilliferous flowers on the same plant.

Fig. 583. Staminiferous flower of Laurel (*Laurus nobilis*). The perianth is in four divisions, the stamens twelve, in three rows, some of them introrse, others extrorse, opening by hinged valves, as shewn in stamen, *s*. Near the base of the stamens peculiar double glands are seen.

Fig. 584. Pistilliferous flower of Laurel (*Laurus nobilis*). The perianth has four divisions, there is a single pistil, and two abortive or rudimentary stamens.

(Fig. 269, p. 120), Cuckow-pint (Fig. 387, p. 161), Birch (Fig. 389, p. 161), and Indian Corn, the application of the pollen to the pistil may also be easily traced; while, in the case of unisexual flowers, in which the staminiferous and pistilliferous flowers are on separate plants, and hence denominated *diœcious* (♂ : ♀), such as the Willow (Figs. 578 and 579), Hemp (Fig. 47, p. 23, and Fig. 574, 1 and 2), and Poplar, the process of fertilization seems to be accomplished with more difficulty.* In the case of Palms it often happens that, while some flowers are staminate (Fig. 456, p. 188 and Fig. 580), and others pistillate (Fig. 457, p. 189), there are others which are perfect or hermaphrodite (Fig. 581); on this account such plants are called *polygamous* (☿ ♂ ♀). In all cases in which one of the whorls of the essential organs is absent, it is considered as depending on suppression or non-development; and this view is confirmed by the fact that, in many unisexual flowers, the rudiments of the suppressed organ may be seen (Fig. 584), and that in certain circumstances it is developed.

A. *Andrœcium or Staminal Organs.*

288. The stamens are placed immediately within the petals. When there is one whorl the stamens are usually equal in number to the petals, and alternate with them (Figs. 585 and 586). When the stamens are twice as many as the petals, they are in two whorls, alternating with each other (Figs. 587 and 588). When there are more than two whorls, each successive verticil alternates with that preceding it (Figs. 589 and 590). When, in place of being alternate with the petals, the stamens are opposite to them, as in the Primrose (Fig. 591), the abnormality is considered as depending, either on the suppression of an outer row, or on transverse chorisis of the petals, or vertical chorisis and union of the stamens. In some cases the stamens are supposed to be opposite the petals, when in reality they are in two rows, as well as the petals. Thus, in the Barberry (Fig. 592), there are six petals in two rows, and six stamens in two rows, and the law of alternation is observed. So also in the Tulip (Fig. 593), and many monocotyledons, with a six-leaved coloured perianth, in two rows, and six stamens.

289. In cases in which the stamens are not equal in number to the petals, the abnormality may be traced to suppression of a certain number, to abortion, adhesion, or chorisis. In Cruciferous plants there are four sepals, four petals, and six stamens, four of which are longer than the others (Figs. 594 and 595). It is supposed that in this case each pair of long stamens is in reality one which has been split by lateral chorisis. This is confirmed by finding teeth only on one side of the filaments of these stamens, while in the two shorter ones

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* The facts connected with the application of pollen, and the fertilisation of the pistil, will be fully considered under Physiology.

teeth exist on both sides, and also by the fact that partial adhesions

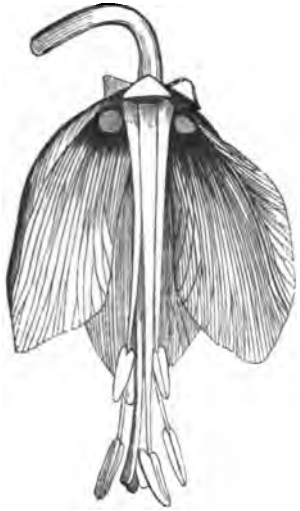

Fig. 587.

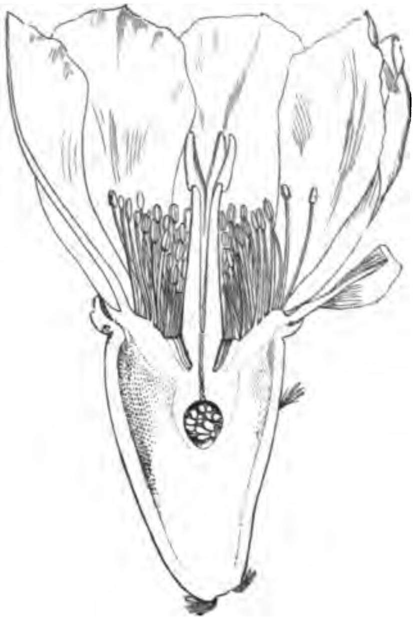

Fig. 589.

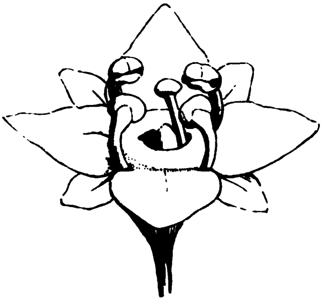

Fig. 585.

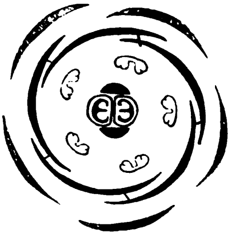

Fig. 586.

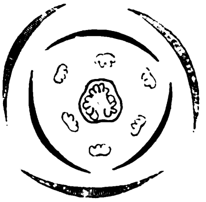

Fig. 588.

Fig. 585. Flower of Lady's mantle (*Alchemilla vulgaris*). It is tetramerous, having four divisions of the calyx or outer perianth, alternating with four of the corolla or inner perianth, and four stamens alternating with the latter. There is a ring and contraction at the opening of the tube of the perianth. The anthers open transversely. The style arises from the apparent base of the ovary, which is seen projecting slightly beyond the ring.

Fig. 586. Diagram of the flower of the Periwinkle (*Vinca*). There are five divisions of the calyx, alternating with five of the twisted corolla, five stamens alternating with the corolline segments, and two divisions of the pistil.

Fig. 587. Flower of Crown Imperial (*Fritillaria imperialis*) laid open. The perigone is in six parts, three of which have been removed. The three outer, one of which is left, may be called the sepals, the three inner, two of which are left, the petals. The stamens are double the number of the petals, and are in two rows. At the base of the petals rounded depressions exist, which are nectariferous glands.

Fig. 588. Diagram of the flower of Meadow Saffron (*Colchicum autumnale*). The divisions of the perianth are six, in two rows, and so are the stamens, while the pistil has three parts.

Fig. 589. Flower of Opuntia vulgaris, laid open vertically, showing numerous stamens attached to the calyx, which is adherent to the ovary and appears above it.

between them are sometimes seen, as in Streptanthus, and that some cruciferous plants have only four stamens.

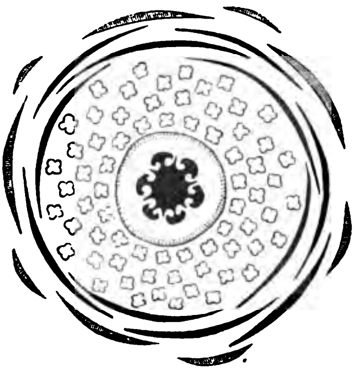

Fig. 590.

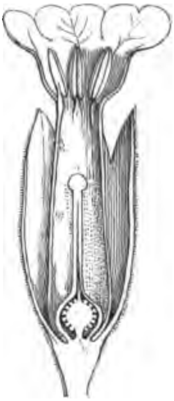

Fig. 591.

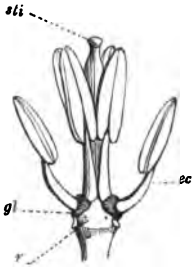

Fig. 595.

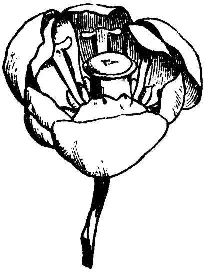

Fig. 592.

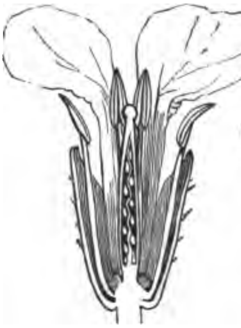

Fig. 594.

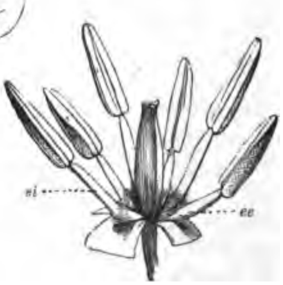

Fig. 593.

290. A perfect stamen, consists of two parts, the *filament* (Fig.

Fig. 590. Diagram of the flower of Opuntia, showing the numerous divisions of the calyx and corolla, and the indefinite stamens arranged in a series of verticils.

Fig. 591. Flower of Primrose (*Primula*), cut vertically, showing the stamens, with very short filaments attached to the corolla, and opposite to its segments. This opposition is caused either by the suppression of an outer whorl of stamens, or by chorisis. The pistil is seen in the centre with ovary, style, and stigma, and a free central placenta, bearing numerous ovules or young seeds.

Fig. 592. Flower of Barberry (*Berberis vulgaris*). There are six petals in two rows, and six irritable stamens, also in two rows, following the law of alternation. The peltate stigma is seen in the centre.

Fig. 593. Andrœcium and Gynœcium of Tulip (*Tulipa sylvestris*). The Perigone is in six parts, three being external, representing the sepals, and three internal, representing the petals. The stamens are six, in two rows, an outer, *ee*, alternate with the petals, and opposite the sepals, while the inner row, *ei*, is alternate with the outer row, and consequently opposite the petals.

Fig. 594. Flower of Radish (*Raphanus sativus*), cut vertically, showing the two short stamens opposite to each other, and one of the pairs of long stamens, supposed to be formed by the lateral chorisis, or splitting of a single stamen. The plant is cruciferous and tetradynamous.

Fig. 595. Essential organs of Wallflower (*Cheiranthus Cheiri*). There are four long stamens in pairs, and two short ones, *ec*. The flower is tetradynamous. The receptacle or thalamus is marked *r*, glands at the base of the stamens, *gl*, and the stigma, *sti*.

596, *f*), representing the petiole of the leaf, and the *anther* (Fig. 596, *a*) analogous to the blade, containing minute cells, in the form of *pollen* (Fig. 596, *p p*). The filament, like the petiole, is sometimes wanting, and the anther is then sessile. The filament is usually arti-

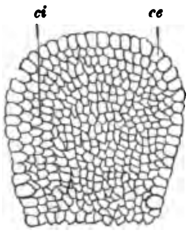

Fig. 597.

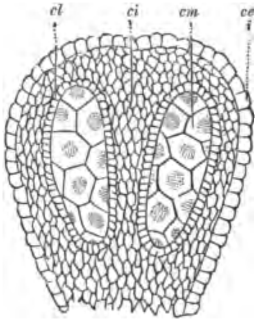

Fig. 599.

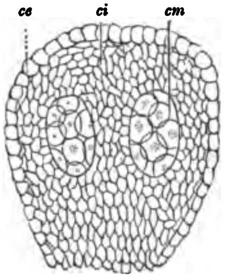

Fig. 598.

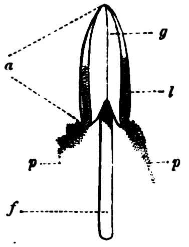

Fig. 596.

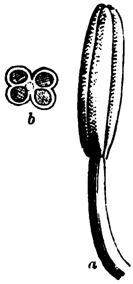

Fig. 602.

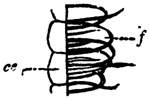

Fig. 601.

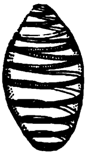
Fig. 600.

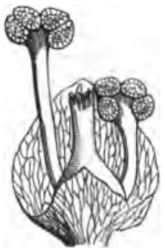
Fig. 603.

Fig. 596. Stamen with its filament, *f*, anther lobes, *a*, connective or union of the lobes, *g*, suture or line of dehiscence, *l*, which is longitudinal and lateral, pollen or antherine fertilising powder, *pp*.

Fig. 597. Vertical section of the young anther of Melon (*Cucumis Melo*). It consists entirely of cells, some of which form an outer epidermal row, *ce*, and others fill up the interior, *ci*.

Fig. 598. Vertical section of an anther-lobe of the Melon in the progress of growth, shewing two large central cells, *cm*, filled with smaller nucleated cells. The outer epidermal layer, *ce*; the inner cells, *ci*, being partially absorbed.

Fig. 599. Vertical section of an anther-lobe of the Melon, shewing the two large central cells filled, with other cells, containing pollen, *cm*. The latter are called mother pollen-cells. The two large cells in the centre are now being surrounded by a special covering, *cl*, which constitutes ultimately the endothecium, or inner lining of the anther. The parenchyma, *ci*, is being absorbed. The outer epidermis, *ce*, constitutes the exothecium, or outer covering of the anther. The endothecium, and the cells between it and the exothecium usually contain spiral fibres.

Fig. 600. Cell containing a spiral fibre coiled up in its interior. Such cells constitute the inner antherine lining.

Fig. 601. Broken down fibrous cells, *f*, of the endothecium of the anther of the Melon. The walls of the cells are absorbed, and the fibres are set free. The exothecium or outer epidermis is marked, *ce*.

Fig. 602. Quadrilocular or Tetrathecal anther of the flowering Rush (*Butomus umbellatus*). The anther entire, *a*, with its filament; section of anther, *b*, showing the four loculi.

Fig. 603. Flower of Duckweed (*Lemna*), showing the two stamens, with quadrilocular anthers. The pistil is in the centre, and the whole flower is covered by a membranaceous urceolate (urn-like) spathe.

culated to the thalamus (Fig. 595, *r*), so that the stamen falls off after performing its functions; but in some instances it is persistent and not articulated. In the case of leaves, the petiole is sometimes united to the blade by a joint, and at other times it is continuous with it, and so it is in the case of the union between the filament and the anther.

291. In the filament cellular tissue exists in a condensed form, surrounding a central bundle of spiral vessels, which represents the fibrovascular system of the petiole. It has a thin epidermal covering, which sometimes presents stomata. Cellular prolongations also occur in the form of hairs, as in the Virginian Spiderwort (Tradescantia), Anthericum, and Verbascum where the stamens are called *stupose*, and in Anagallis tenella, where the hairs have a beautiful knobbed appearance.

292. The anther, like the lamina of the leaf, is developed before its stalk. It consists originally of a cellular mammilla, containing a mass of thin-walled cells (Fig. 597, *ce* and *ci*). In the progress of growth larger cells are produced in the interior (Figs. 598 and 599, *cm*), forming four separate clusters, each of which is surrounded by a special cellular covering (Fig. 599, *cl*). These larger cells are destined for the formation of pollen, and the four places at which their development commences may be seen on a transverse section of a very young anther. These clusters of pollen-cells increase in size, and gradually cause absorption of the surrounding parenchyma (Figs.

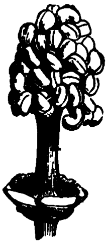

Fig. 604.

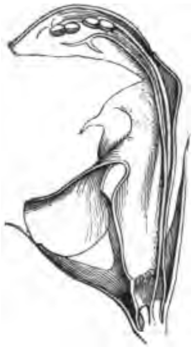

Fig. 605.

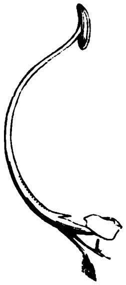

Fig. 606.

Fig. 604. Andrœcium of Mallow (*Malva*). The stamens are monadelphous, *i. e.* united into one cluster by their filaments. The anthers are one-celled, and open by a slit all round. Some suppose that the anther lobes diverge at the base, and unite at the apex in such a way as to form a single cavity by obliteration of the septum. From its appearance the Andrœcium is sometimes called Columnar.

Fig. 605. Flower of Dead nettle (*Lamium*), cut vertically, showing one of the long and one of the short stamens, with the two antherine lobes in each, united by their base, so as to form apparently one cavity. The corolla is labiate, and the stamens didynamous.

Fig. 606. A branch of the long distractile connective of Sage (*Salvia*), bearing a single anther lobe.

598 and 599, *ci*). It generally happens that two of the adjacent clusters of pollen cells unite by obliteration of their special covering at one side, and thus ultimately two pollen cavities are found in the anther, in place of four.

293. In its fully developed state, the anther presents two *lobes* (Fig. 596, *l*), like the two halves of the blade of the leaf; these lobes being separated by a partition, called the *connective* (Fig. 596, *g*), representing the midrib, and consisting of cells and spiral vessels. Each anther lobe has one or two cavities, which are receptacles of the cellular grains of pollen. These cavities correspond to the large cells seen in Figure 599, *cm*, with their special covering, *cl*, which forms the inner lining of the anther case, called *endothecium*. This lining consists of spiral cells (Fig. 600), which are elastic, and assist in bursting the outer epidermal covering of the anther called *exothecium*, corresponding to the cells marked *ce* in Figures 598 and 599. In the cells of the endothecium, as the anther approaches to maturity, the membrane becomes sometimes obliterated, so that the delicate fibres alone are left, as is seen in the Melon (Fig. 601), and in Cobæa. These spiral fibres appear also to fill up the space between the two coverings in many full-grown anthers.*

294. Thus the anther represents the lamina of a leaf, with its two halves divided by a midrib, surrounded with a double epidermal covering (the inner being fibro-cellular), and containing cellular tissue, which assumes the form of pollen. When there are four cavities (loculi or thecæ as they are called) in the anther, they may be considered as representing the two halves of the leaf, each with its upper and lower stratum of cells. This division into four is seen in the young state of anthers, and is considered as the normal state. When it is seen in the fully developed anthers they are called *quadrilocular* or *tetrathecal* (Figs. 602 and 603). When, owing to obliteration of some of the partitions, only two loculi remain, as is very generally the case, the anther is *bilocular* or *dithecal* (Fig. 596, *a*).

295. It happens occasionally that, by the suppression of one lobe, as in Gomphrena, or by the disappearance of the partition between the two lobes, the anther becomes *dimidiate*, or one-celled. In the Mallow tribe (Fig. 604) the divergence of the base of the anther lobes, and their complete union at the apex, render them one-celled (unilocular, monothecal); while in Labiate plants (Fig. 605), by the turning of one of the lobes, a union takes place by their bases so that they form one cavity. The long connective of the Sage and other species of Salvia separates the anther lobes, so that each appears a monothecal anther (Fig. 606), one of which contains pollen, while the other is abortive.

296. The stamens vary in number, and names are given to flowers accordingly. Thus,—

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* See Purkinje, de cellulis antherarum fibrosis, Vratislav. 1830.

A flower having 1 stamen is Monandrous (Fig. 556, p. 210). Hippuris.
„ „ 2 stamens is Diandrous (Fig. 578, p. 216). Veronica.
„ „ 3 stamens is Triandrous (Fig. 561, p. 211). Grasses.
„ „ 4 stamens is Tetrandrous (Fig. 573, p. 215). Alchemilla.
„ „ 5 stamens is Pentandrous (Fig. 571, p. 215). Primula.
„ „ 6 stamens is Hexandrous (Fig. 572, p. 215). Tulip.
„ „ 7 stamens is Heptandrous, as in Trientalis, and Æsculus.
„ „ 8 stamens is Octandrous, as in Heaths, and Epilobium.
„ „ 9 stamens is Enneandrous (Fig. 577, p. 216). Butomus.
„ „ 10 stamens is Decandrous (Fig. 448, p. 186). Saxifrage.
„ „ 12 stamens is Dodecandrous (Fig. 583, p. 217). Asarum.
„ „ 20 stamens is Icosandrous (Fig. 530, p. 206). Strawberry.
„ „ numerous and indefinite stamens is Polyandrous ∞ (Fig. 589, p. 219). Poppy.

The Greek numerals are prefixed to the word, meaning male, or stamen. In the common Mare's-tail there is only one stamen in each flower, while in Cereus nycticalus 400 have been counted. The number of the stamens determines some of the classes in the Linnæan artificial system of classification.

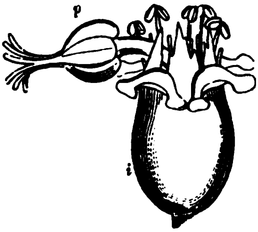


Fig. 607.

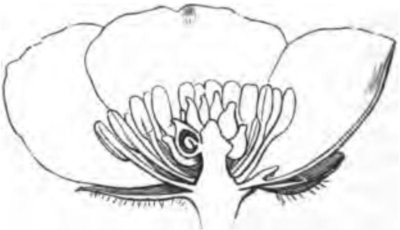


Fig. 608.

297. In the case of Euphorbia (Fig. 609), flowers are met with, consisting of a single stamen (Fig. 610), and others consisting of a single pistil. These, when enclosed in one common involucre, or bracteal envelope (Fig. 607, *i*), seem to be stamens and pistils in the same flower. But on examination it is seen that a joint occurs at a part of the supposed filament (Fig. 610, *a*), indicating its connection with the peduncle, *p*, and so also in the case of the pistil (Fig. 607, *p*). In some of the species of Euphorbia a proper floral envelope appears at the joint indicating the true nature of the organ. The flowers represented in Figures 607 and 610 are therefore naked or achlamydeous male and female flowers on one plant, which is therefore said to be monœcious.

Fig. 607. Numerous male and one female flower, *p*, of Euphorbia, enclosed in a common involucre, *i*, composed of gamophyllous bracts. The plant is monœcious.

Fig. 608. Flower of Crowfoot (*Ranunculus*), cut vertically, shewing numerous stamens inserted into the receptacle (thalamus), below the pistil. The stamens are hypogynous. The flower is polyandrous.

298. The position of the stamens is normally within the petals, and outside the pistil. They arise from the part of the peduncle below the latter, and hence they are *hypogynous*, which means under the pistil (Figs. 608 and 611). But, as in all other parts of the flower, adhesions take place by which changes in apparent position are produced. Thus the stamens, in place of being free and truly hypogynous, sometimes adhere to the tube of the calyx, becoming *perigynous*, which means surrounding the pistil (Figs. 612 and 613); while at other times they adhere completely to the ovary, and appear to arise from the top of it, and are hence called *epigynous* (Figs. 614 and 615). When the stamens adhere still more completely to the pistil, the union

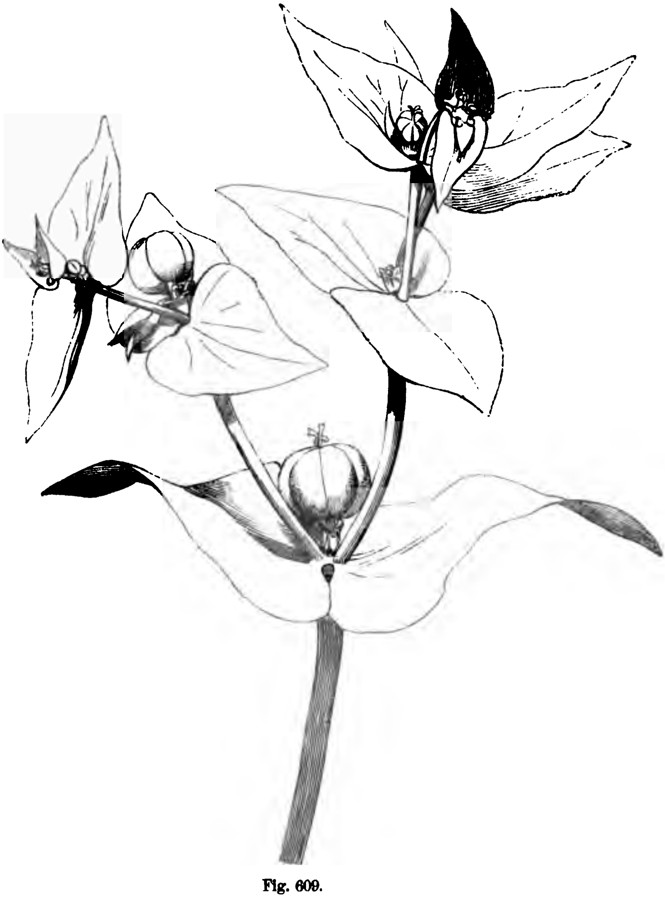


Fig. 609.

Fig. 609. Flowering stalk of Caper Spurge (*Euphorbia Lathyris*), shewing clusters of male and female flowers, surrounded by involucres. The plant yields milky juice of an acrid nature.

extending above the ovary, they become *gynandrous*, as in Orchis (Fig. 616), and Birthwort (Fig. 617), and form with the pistil a column in the centre of the flower.

299. In place of adhering to the contiguous organs, the stamens may be distinct from them, but united to each other either by their anthers or by their filaments. When the filaments are combined into one mass, more or less completely, the flowers are *monadelphous*, as in the Mallow (Fig. 618), and Yew (Fig. 619); when in two sets or bundles they are *diadelphous*, as in Fumitory (Fig. 359, p. 152), and in some papilionaceous flowers, in which the bundles are often unequal, nine stamens being united in one set, and only one (which is superior) in the other (Fig. 620); when in three sets, they are *triadelphous*, as in St. John's Wort (Fig. 621); and when in more sets *polyadelphous*, as in the Castor-oil plant (Fig. 622). The numerous stamens in the Mallow and St. John's Wort, and Castor-oil plant, are by some traced to collateral chorisis, or repeated divisions of the stamens. Sometimes the filaments are united by means of an interposed membrane (a sort of crown), as in the Pancratium. When the stamens are united by their anthers, the flowers are termed *syngenesious* or *synantherous*, as in Compositæ (Fig. 542, p. 208), in Violet (Fig. 649, p. 234), and in Lobelia.

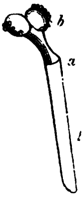


Fig. 610.

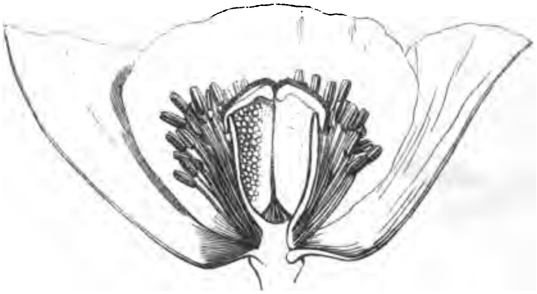


Fig. 611.

300. Stamens are often shorter than the corolla, and are then said to be *included* (Fig. 623); but at times they elongate and extend beyond it, when they are *exserted*, as in the Jalap plant (Exogonium Purga), and in Valerian (Fig. 624). In some flowers we find certain stamens constantly longer than others. Thus, in many Labiate flowers (Fig. 605, p. 222), and in Frogsmouth (Fig. 625), we meet with two long and two short stamens, the flowers being *didynamous*,

Fig. 610. Male flower of Euphorbia. The whole flower consists of a stamen, *b*, supported on a peduncle, *p*, to which it is united by an articulation at *a*. The flower is naked (achlamydeous). In some Euphorbias a perianth appears at the joint.

Fig. 611. Vertical section of the flower of the Poppy (*Papaver*). The stamens are numerous, indefinite, and inserted into the thalamus below the pistil. They are therefore hypogynous. The flower is polyandrous. The plant belongs (like Ranunculus) to the class Polyandria of Linnæus, and to the Dicotyledonous sub-class called Thalamifloræ by De Candolle.

and in Cruciferous flowers (Figs. 594 and 595, p. 220), there are four long and two short, the flowers being *tetradynamous*. Stamens in general stand regularly round the pistil, but occasionally their upper portions are curved to one side of the flower, and they become declinate, as in the Amaryllis and Horse-chestnut (Fig. 335, p. 143).

301. The filament is slender and cylindrical, or slightly flattened. It is curved and elastic in the Pellitory (Figs. 626 and 627) and in the Nettle (Fig. 628), petaloid in the White Water Lily (Fig. 629), and in Indian Shot and Ginger, broadened at the base in Campanula (Fig. 630), thickened in Barberry (Fig. 645, p. 233), with appendages

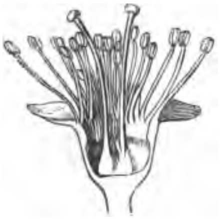
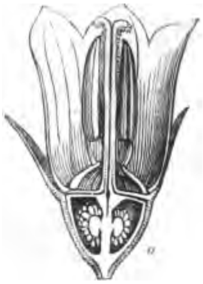


Fig. 612.



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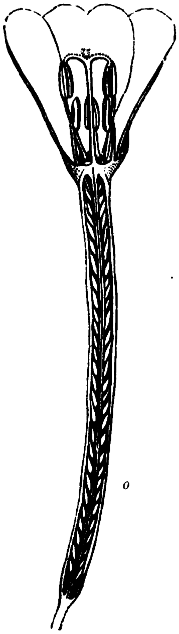


Fig. 614.

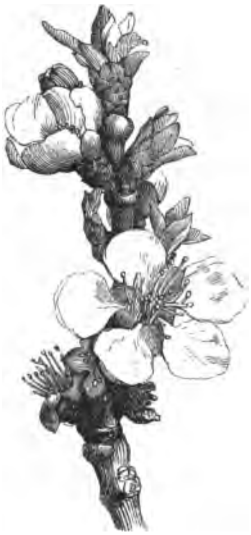


Fig. 613.

Fig. 612. Vertical section of the flower of the Cherry (*Cerasus*). There are numerous indefinite stamens inserted on the calyx; hence they are perigynous. Some call such a flower Calycandrous, *i.e.*, having numerous stamens adherent to the calyx. In the centre of the flower is the pistil, composed of two carpels.

Fig. 613. Flowering branch of Apricot (*Prunus Armenaica*). The stamens are numerous and adherent to the calyx. The flowers are calycandrous, and the plant belongs to the class Icosandria of Linnæus, and to the Dicotyledonous sub-class called Calycifloræ by De Candolle.

Fig. 614. Flower of Willow-herb (*Epilobium*). The stamens appear to arise from the top of the ovary, *o*, and are called epigynous. They are adherent to the calyx, the tube of which is united closely with the ovary.

Fig. 615. Flower of Bell-flower (*Campanula*), cut vertically. The stamens appear to arise from the summit of the ovary, *o*, and are called epigynous. The tube of the calyx is adherent to the ovary. The lower part of the filament is broad, and conceals the upper part of the ovary when viewing the interior of the flower from above. On the style there are hairs which collect the pollen after it is scattered. The ovary is opened, and shows the placenta and ovules.

in Borage (Fig. 631) and Asclepias (Figs. 632 and 633). Some of the staminal appendages are traced to vertical and transverse chorisis. The filament is attached to the anther lobes, either by adhering along their whole length on one side, called the *back*, and the anther is then *adnate*, as in Magnolia, Crowfoot (Fig. 608, p. 224), and Barberry (Fig. 645, p. 233); or it extends only to the base of the lobes,

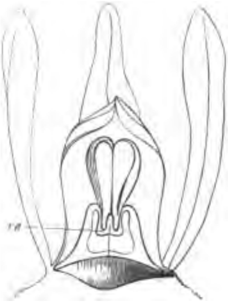
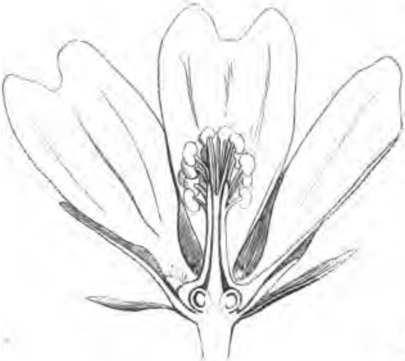


Fig. 616.



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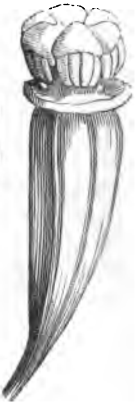

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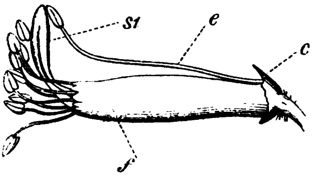

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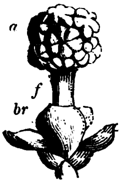

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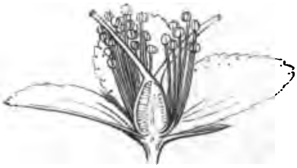


Fig. 621.

Fig. 616. Upper part of the Gynandrous flower of an Orchis. The stamen and pistil are united into a common column (Gynostemium). The lobes of the anther are placed immediately above the stigma. They contain pollen masses (pollinia), which are adherent to a point above the stigma, by means of a viscid tenacious matter, called retinaculum, *re*. Immediately below the anther is a viscid space constituting the stigma. The lower part of the column, with the ovary, have been removed.

Fig. 617. Essential organs of Birthwort (*Aristolochia*). The lower part of the figure is the ovary, and above it are the stamens united in a column with the style, so as to be gynandrous. On the summit is the stigma above the stamens.

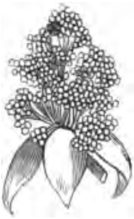
Fig. 618. Vertical section of the flower of Mallow (*Malva*). The stamens are monadelphous, being united by their filaments into a cluster round the pistil.

Fig. 619. Male (sterile, staminiferous) flower of Yew (*Taxus baccata*). The bracts, *br*, at the base, are imbricated, the stamens are united into a bundle by their filaments, thus being monadelphous, while their anthers, *a*, are free. Some consider this a single stamen, with the connective dividing into numerous parts, each bearing an anther lobe.

Fig. 620. Stamens and pistil of Sweet Pea (*Lathyrus*). The stamens are diadelphous, nine of them being united by their filaments, *f*, while one of them, *e*, is free; the upper part of the pistil is marked, *st*, the calyx, *c*.

Fig. 621. Vertical section of the flower of St. John's Wort, in which the stamens are formed into three bundles by the union of their filaments. The flower is triadelphous. Two of the bundles are seen in the figures, the third having been removed. In the centre is the pistil, with the ovary containing ovules, ending in the style and stigma.

which are firmly fixed to it, and the anther is *innate*, as in Carex (Fig. 634), and Scirpus (Fig. 635), and Hemp (Fig. 574, 1, p. 216);



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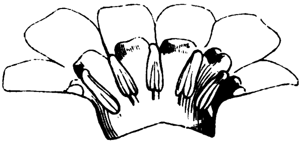

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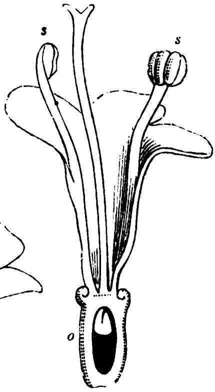

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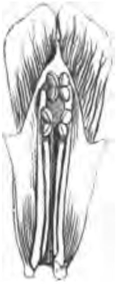

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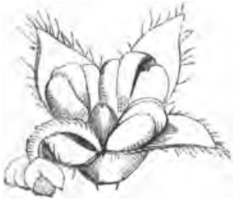

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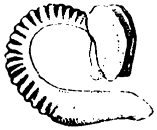

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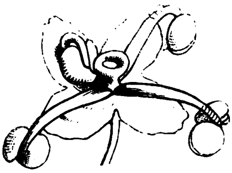


Fig. 628.

or its apex is attached to a single point of the anther, which then

Fig. 622. Male flower of Castor-oil plant (*Ricinus communis*). The perianth is reflexed, and the stamens are seen in numerous clusters, united by their filaments. The flower is polyadelphous. The different clusters are branching, owing to the filaments being united up to different heights.

Fig. 623. Corolla of Forget-me-not (*Myosotis*), laid open and spread out. The five stamens are included, *i.e.* not pushed out beyond the flower; they are attached to the tube of the gamopetalous rotate corolla, and their filaments are very short. Scales exist on the corolla, alternating with the stamens.

Fig. 624. Flower of Valerian (*Valeriana*), cut vertically. There are two exserted stamens, *s s*, left, which are epigynous, or attached apparently to the upper part of the ovary, *o*, which terminates in the style and bifid stigma. The ovule is pendulous.

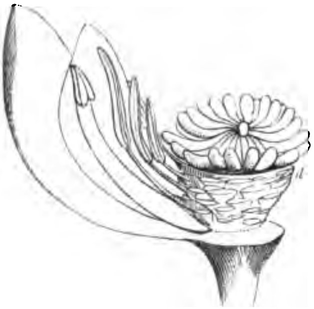
Fig. 625. Didynamous flower of Frogsmouth (*Antirrhinum majus*), having two long and two short stamens. The anther lobes in each stamen are united by their bases, so that the line of dehiscence passes continuously through both. The stamens are attached to the corolla, and are said to be epicorolline. The flower is unsymmetrical, owing to the suppression of the fifth stamen.

Fig. 626. Male flower of Pellitory (*Parietaria officinalis*). It contains four stamens, the filaments of which are incurved in the early state, and ultimately bend back with elastic force, so as to scatter the pollen. There are four divisions of the perianth. The flower is monochlamydeous. The abortive rudiment of a pistil is seen in the centre.

Fig. 627. Stamen of Pellitory (*Parietaria*), with its two-lobed anther, and elastic curved filament.

Fig. 628. Male flower of Nettle (*Urtica*), with four stamens, having elastic incurved filaments in the young state. When the four-leaved perianth expands, the stamens, as shewn in the figure, bend outwards, and the anthers are pushed beyond the flower.

swings easily about, and is called *versatile*, as in Grasses (Fig. 637), the Lily, the Meadow-saffron (Fig. 636, *b*), and the Evening Primrose.



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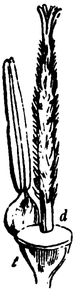
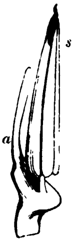


Fig. 630.



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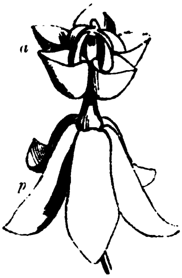

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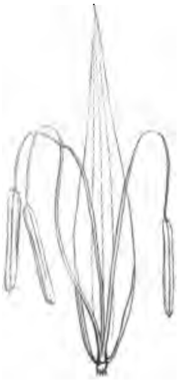

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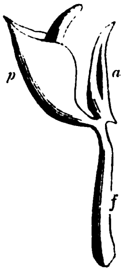

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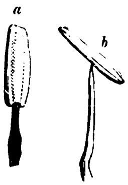

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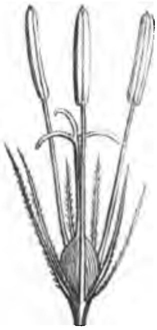


Fig. 635.

Fig. 629. Section of the flower of the White Water Lily (*Nymphæa alba*). The receptacle ends in a large fleshy disk, *d*, covering the ovaries. Into this prolongation of the receptacle the petals and stamens are inserted. The filaments of the outer stamens are petaloid. In this flower there is a gradual transition from stamens to petals.

Fig. 630. Pistil and stamen of Bell-flower (*Campanula*). The filament of the stamen is dilated at the base. The calyx is attached to the ovary, *t*, which opens by slits through the calyx. The disk-like upper portion of the ovary is marked, *d*. On the style are numerous rows of hairs.

Fig. 631. Stamen of Borage (*Borago officinalis*). The anther lobes, *s*, are pointed, the filament is appendiculate, *i.e.*, is furnished with an appendage, *a*, in the form of a long slightly-curved process.

Fig. 632. Flower of Asclepias, shewing the united stamens surrounding the pistil. The stamens are furnished with remarkable hollow and horn-like appendages, *a*, which form a staminal crown. The petals and sepals, *p*, are reflexed.

Fig. 633. One of the stamens of Asclepias removed, shewing the filament, *f*, and anther, *a*, containing pollen masses, and the peculiar processes, *p*, which form an appendage to the stamen.

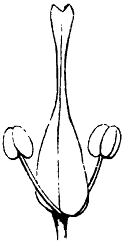
Fig. 634. Male flower of a species of Sedge (*Carex*). It consists of a glume or scale supporting three stamens, with slender thread-like filaments, and innate anthers.

Fig. 635. Flower of a kind of Club-rush (*Scirpus*). The glumaceous perianth has been removed, and there are seen six hypogynous toothed bristles, three stamens with innate anthers, and a single pistil with three stigmas at the summit of the style.

Fig. 636. Two stamens of Meadow-saffron (*Colchicum autumnale*), one, *a*, with the anther unmoved, the other, *b*, with the anther so placed as to show its versatile character, the filament being attached by a point.

302. The anther presents a groove or depression between its lobes, indicating the place where the septum or partition is situated (Figs. 628 and 638). Each anther lobe also presents a line or furrow running from top to bottom, and placed more or less laterally (Figs. 637 and 639). This is called the *suture*, or line of dehiscence, and marks the place where the anther opens to discharge the pollen. (Fig. 596, p. 221, and Fig. 640). The suture corresponds to the edge of the leaf, and in innate anthers it is lateral, while in others its position is more or less distinctly on the *face* of the anther (Fig. 571, p. 215), or on the side opposite to the attachment of the filament. At the suture the epidermal tissue is thin, and the endothecium is wanting.

303. The face of the anther is usually directed towards the centre of the flower, in which case the anther is called *introrse*, as in Magnolia, Nymphæa (Fig. 629, p. 230), and the Vine (Fig. 571, p. 215); at other times it is directed towards the circumference of the flower, and the anther is *extrorse*, as in the Meadow-saffron (Fig. 641), in the Iris, and in the Tulip-tree (Fig. 259, p. 116). The mode of opening or of dehiscence varies in different anthers. Sometimes the lobes split along the whole face, either in the centre or at the side, longitudinally (Fig. 414, p. 174, and Fig. 640), at other times transversely (Fig. 642). Sometimes the slit only takes place at the apex, so as to present two holes or pores, as in Rhododendron and Solanum



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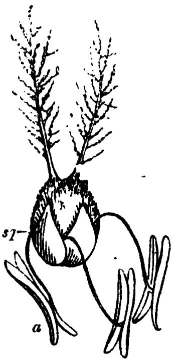

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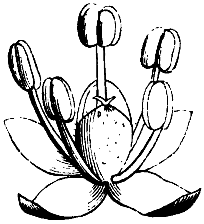

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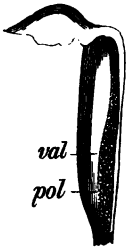


Fig. 640.

Fig. 637. Grain of Wheat (*Triticum*), with its glumes and glumellulæ removed. Two scales or lodiculæ, *sq*, are seen at the base of the ovary. There are three stamens with thread-like filaments and versatile anthers, *a*, and two feathery styles at the summit of the ovary.

Fig. 638. Naked flower of the Ash (*Fraxinus excelsior*), shewing two stamens and one pistil. The anther has a groove on its surface indicating the separation between its two lobes.

Fig. 639. Flower of Goosefoot (*Chenopodium*), with a single perianth (monochlamydeous, or mono-perianthous), of five pieces, and five stamens shewing the two lobes of each anther, and the mark along the edges where the suture or line of dehiscence exists. The anthers open towards the pistil, which is in the centre. They are called antheræ introrsæ, or anticæ.

Fig. 640. Stamen of Fir (*Pinus*), shewing the line of longitudinal dehiscence, with the valve, *val*, and the pollen, *pol*, in the interior.

(Fig. 643), or four pores, as in Poranthera, or two tubes, as in the Heath (Fig. 644), or so as to form a separable lid, as in Gamboge. In Mayaca, the anther terminates in a tube one-third the length and diameter of the anther itself, and the pollen is discharged at the apex of the tube. In the Barberry (Fig. 592, p. 220, and Figs. 645 and 646), each lobe of the anther opens by a single valve, which is rolled upwards; and the same thing occurs in many Lauraceæ (Fig. 647), in which, however, there are frequently four valves, that is, two to each lobe, corresponding to the antherine cavities.

304. The union of the anther lobes is effected either by a continuation of the filament (Fig. 645), or by a mass of cellular tissue with spiral vessels, called the *connective* (Fig. 571, p. 215). This extends to a greater or less height between the lobes, and is sometimes so narrow as to be inconspicuous, as in Euphorbia. Sometimes it reaches beyond them in the form of a cellular expansion, as in Magnolia and Asarum, or of a long feathery appendage, as in Oleander (Fig. 648, *f*); while at other times it proceeds backwards in the form of a spur, as in the Violet (Figs. 649 and 650, *c*), and in the Heath (Fig. 644). In the Lime-tree it separates the two antherine lobes distinctly (Fig. 651, *a*). It divides into two branches occasionally, each bearing an anther lobe, as in Sage (Fig. 606, p. 222), and then it is *distractile*. The anther lobes are sometimes separated by the connective, so as to become horizontal, as in Stachys, and then their dehiscence appears to be transverse. The anther lobes present various forms, such as round (Fig. 639, p. 231), globose (Fig. 628, p. 229), elliptical (Fig. 636, p. 230), pointed (Fig. 631, p. 230, and Fig. 644), flexuose, as in the Gourd tribe (Fig. 652), and forked, as in Acalypha.

305. The *Pollen* is contained in the anther, and presents the appearance of a minute, usually yellow powder, which, when examined by the microscope, is found to consist of cellules (Fig. 653) of different forms, varying from $\frac{1}{300}$ to $\frac{1}{700}$ of an inch in diameter. Pollen-grains, when fully formed, are usually spherical (Fig. 662, p. 236), oval (Fig. 660, p. 236), or trian-

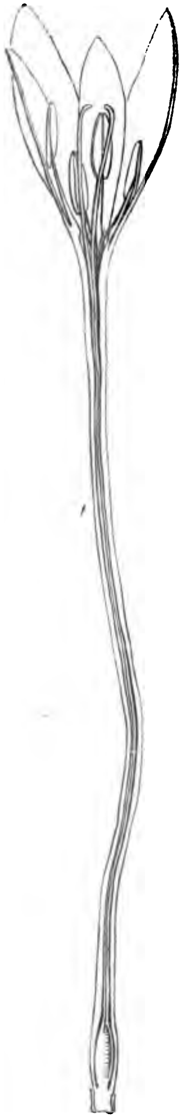


Fig. 641.

Fig. 641. Flower of Meadow-saffron (*Colchicum autumnale*), cut vertically. The perianth is double and coloured. Its tube, *t*, is very long. The stamens are attached to the tube, and the anthers open on the outside extrorsely. They are called antheræ extrorsæ, or posticæ.

gular (Fig. 664, p. 236). In Bladder-Senna they are of a square form, in Virginian Spiderwort cylindrical, and in the Hazel polyhedral. In Podostemon the pollen is of an oblong shape, with an hour-glass contraction in the middle; while in Zostera it is a beautiful microscopic object, consisting of long slender threads.

306. Pollen-grains are developed in the large cells seen in the early state of the anther (Figs. 598 and 599, *cm*, p. 221). Each of these cells is called a parent or mother cell (Fig. 654, *cm*). Its contents divide first into two, and then into four parts, each of which becomes covered with cellulose, so as to constitute independent cells or pollen-grains (Fig. 654, *p*). These grains either burst through the parent cell and become free, or they remain united in fours or some multiple of four, as in many species of Acacia; or in large masses, such as those seen in Orchids (Figs. 655 and 656), and in Asclepias (Fig. 657), where they constitute *pollinia*. The remains of the partially destroyed mother cells sometimes remain in the form of threads.

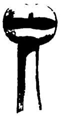
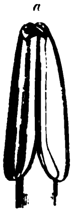


Fig. 642.



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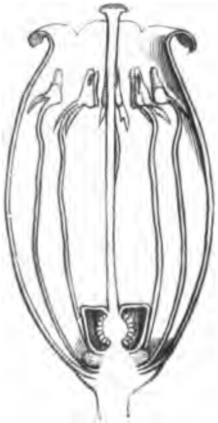

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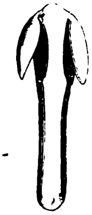
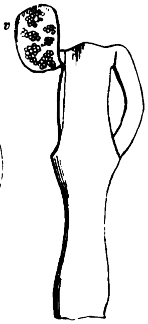


Fig. 645.



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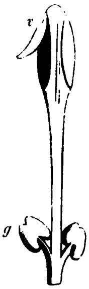


Fig. 647.

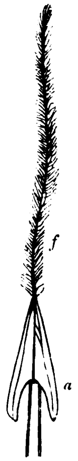


Fig. 648.

Fig. 642. Stamen of Lady's Mantle (*Alchemilla*), with the anther opening transversely. It is called transversely-dehiscent.

Fig. 643. Stamen of a species of Nightshade (*Solanum*), showing the divergence of the anther lobes at the base, and the dehiscence by pores at the apex, *a*.

Fig. 644. Flower of Heath (*Erica*) cut vertically. The corolla is urceolate or urn-like; the stamens are eight in number; the anthers open in a porous manner by tubes at the apex, and from each connective two spur-like processes arise.

Fig. 645. Adnate anther of Barberry (*Berberis vulgaris*). The lobes of the anther open by hinged valves.

Fig. 646. The stamen of the Barberry (*Berberis vulgaris*), showing one of the valves of the anther, *v*, curved upwards, bearing the pollen on its inner surface.

Fig. 647. One of the stamens of the Sweet Bay (*Laurus nobilis*), in which the anthers open by recurved valves, *v*. These are generally four in number. At the lower part of the filament two anther-like stalked glands, *g*, are seen. These are probably an abortive state of the stamens.

Fig. 648. Stamen of Rose Bay (*Nerium Oleander*), with sagittate anther lobes, *a*, and a long feathery process, *f*, proceeding upwards from the connective.

307. Each pollen-grain has usually two coverings, the outer called *extine*, being a firm membrane marked frequently with bands, reticulations, or rough points (Fig. 658); the inner, denominated *intine*, being thin and capable of extension. The intine alone is present in Zostera, and some consider this covering as that first formed, the outer being a secretion from it. In the ripe pollen of the Fir (Fig. 659), the distension of the intine is such as to separate the extine into two hemispherical parts. Movements have been observed in the pollen grains of Cereus speciosissimus and some other plants, according to Dr. Horn. The motions have been attributed to minute papillose processes or cilia.

308. In the interior of pollen-grains a minute granular matter exists called *fovilla*, mixed with starch and oily matter. The fovilla granules vary from $\frac{1}{4000}$ to $\frac{1}{30000}$ of an inch in diameter. These display motions which are looked upon by some as molecular, or such as are seen under the microscope among minute particles suspended in fluid, while by others they are regarded as analogous to the phytozoic movements seen in the antheridia of Cryptogamic plants.*

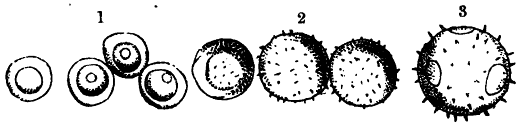
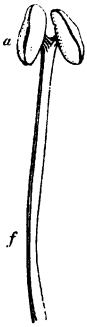


Fig. 653.



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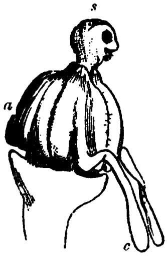


Fig. 649.

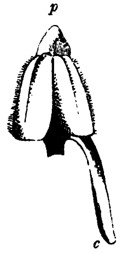
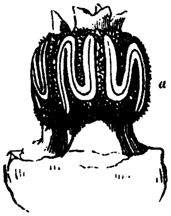


Fig. 650.



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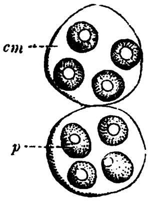

Fig. 654.

Fig. 649. The stamens and pistil of the Pansy (*Viola tricolor*). The five stamens have short filaments, and their anthers, *a*, are united into a tube round the pistil. Two of the stamens have spur-like processes, *c*, proceeding backwards into the corolline spur. The hooded stigma, *s*, is seen at the top of the pistil.

Fig. 650. Two stamens of Pansy (*Viola tricolor*), recurved, with their two anther lobes, and the process, *p*, extending beyond them. One of the stamens has been deprived of its spur, the other shows its spur, *c*.

Fig. 651. Stamen of the Lime-tree (*Tilia*). The two anther lobes, *a*, are separated by the connective at the end of the filament, *f*. Each lobe opens by longitudinal dehiscence.

Fig. 652. Stamens from the male flower of Melon (*Cucumis Melo*), with wavy or sinuous anther lobes, *a*. The anthers are said to be anfractuose.

Fig. 653. Pollen grains of Melon (*Cucumis Melo*), in various stages of development. No. 1, the grains in a young state, and free; No. 2, the grains farther advanced, and nearly ripe; No. 3, a pollen grain in a ripe state, fully developed.

Fig. 654. Parent cells, *cm*, from the anthers of the Melon, each containing four grains of pollen, *p*. The parent cell divides first into two by a merismatic process, and then each of these parts subdivides into two, thus forming four cells. The grains of pollen are represented with nuclei in their interior.

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* See Annales des Sciences Nat. vol. xii. p. 40.

309. The surface of pollen-grains is often marked by grooves or folds (Figs. 660 and 661), and by rounded markings. At these parts the extine is either deficient, or separates like a lid, as in the Passion-flower. When the pollen is moistened in water its grains absorb it and become enlarged, and the intine bursts at one or more points, sending out the fovilla (Fig. 662). When the pollen is scattered on the pistil, and is moistened on one side by the fluid of the stigma (Fig. 663, *stig*), the intine, in place of bursting, protrudes in the form of a tube called a pollen-tube (Figs. 663, *tp*, 664, *t*, and 665, *b*). The number of tubes protruded in different kinds of pollen-grains varies. Amici says that the two pollinia (Fig. 656) of Orchis Morio contain each about 200 secondary small masses (Fig. 665, *a*), composed of grains united in fours, and that each of these small masses present 300 openings capable of emitting tubes.*

310. *Transformations of Stamens.*—Changes take place in the stamens by suppression and degenerations of various kinds. Whenever the stamens are below the number of the parts of the calyx, we may suspect that there has been some suppression. In many irregular flowers, such as Figwort and Dead-nettle, four stamens only occur, although the parts of the calyx and corolla are five. This depends on the suppression of one stamen, and, in the case of Figwort, we

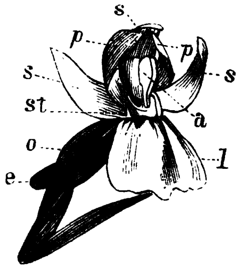
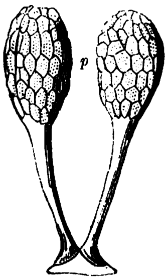


Fig. 655.



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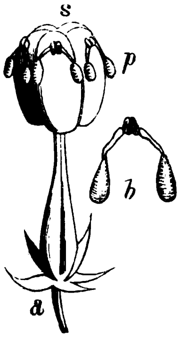

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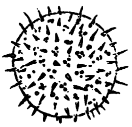

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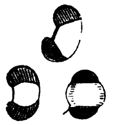

Fig. 659.

Fig. 655. Flower of Orchis, consisting of sepals, *s s s*, petals, *p p*, and labellum, *l*, with its spur, *e*; the ovary, *o*, stigma, *st*, and anther, *a*, containing pollinia or pollen-masses.

Fig. 656. Pollinia, or pollen-masses, separated from the point above the stigma, with their retinacula or viscid matter attaching them at the base. The pollen-masses, *p*, are supported on stalks or caudicles. These masses are easily detached by the agency of insects.

Fig. 657. Pistil of Asclepias, *a*, with pollen-masses, *p*, adhering to the stigma, *s*. Pollen-masses, *b*, separated, united by a gland-like body.

Fig. 658. Round ripe pollen of Hollyhock (*Alcea*), with its extine covered with prominent points.

Fig. 659. Pollen of Fir (*Pinus*), in which, by the increase of the intine, the extine is separated into two hemispherical portions, marked by the dark spaces at each end of the grains.

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* For fuller details regarding pollen, see Mohl, sur la structure et les formes des graines de Pollen, Annales des Sciences, 2d series iii. 148; Fritzsche de Plantarum Polline, Berolin. 1833, and ueber der Pollen, Petersburg, 1837; Hassall on the Structure of the Pollen Granule, in Annals of Nat. History; viii. 92; ix. 93, 544.

find a rudimentary stamen in the form of a staminodium, as shown in Figure 666, where a dark scale is seen attached to the corolla on the upper side. Again, in allied plants, such as Pentstemon, the fifth stamen is produced. In Labiate plants also, allied to the Dead-nettle, the fifth stamen sometimes appears in the form of a thread, terminated by an anther-like body, which, however, is barren. The stamens are suppressed in the case of pistilliferous flowers (Fig. 575, p. 216, and Fig. 579, p. 216). Sometimes they appear in such flowers in an altered and abortive state (Fig. 584, p. 217). The suppression of an outer row of stamens is often indicated by those remaining being opposite the petals (Fig. 458, p. 189). In flowers with numerous stamens, such as Poppies, Roses, and Crowfoots, there are always some of the stamens abortive, for we do not find two flowers in which the number is the same. It seems to be a law in vegetable organo-

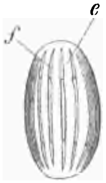
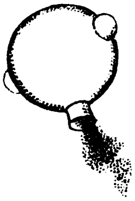


Fig. 660.



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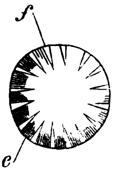

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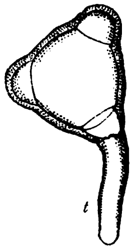
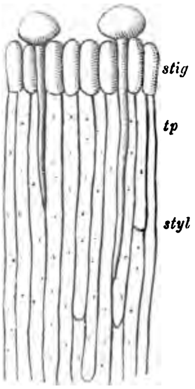


Fig. 664.



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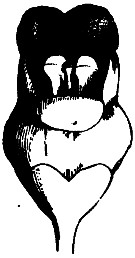

Fig. 666.

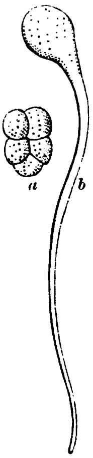

Fig. 665.

Fig. 660. Elliptical pollen of Milk-wort (*Polygala*), viewed lengthwise. Its surface, or extine, *e*, is marked with grooves or slits, *f*, where the intine protrudes.

Fig. 661. The pollen of Polygala, viewed from above, shewing the extine, *e*, with the slits, *f*, for the protrusion of the intine.

Fig. 662. Ripe rounded pollen of Cherry (*Cerasus*), discharging its fovilla through a tubular opening formed by the intine. There are other two points at which the intine is seen protruding.

Fig. 663. Vertical section of the upper part of the pistil of Frogsmouth (*Antirrhinum majus*). Two pollen grains are seen lying on the stigma, *stig*, these send out tubes, *tp*, which pierce the stigma, and penetrate the tissue of the style, *styl*, until they reach the ovules or young seeds.

Fig. 664. Triangular pollen of Evening Primrose (*Œnothera*), with one pollen tube, *t*, protruded. This tube is formed by the intine which is also seen projecting at the other angles.

Fig. 665. Small pollen mass, *a*, of early purple Orchis (*Orchis mascula*). The grains are often united in four, or multiples of four. Pollen tube, *b*, arising from a pollen grain.

Fig. 666. Flower of Figwort (*Scrophularia*). The corolla is subglobose, with two short lips, the upper two-lobed with a scale or abortive stamen (staminodium) attached to it. The lower lip three-lobed, the two lateral lobes straight, and the middle one decurved. There are four developed stamens which are didynamous.

graphy that the number of the floral organs is less constant the greater it is. Instances of Bell-heath and Purple Snap-dragon have been mentioned in which the stamens were entirely abortive.

311. Stamens in some plants have a great tendency to be changed into petals, especially in cultivation. In plants belonging to the Water Lily tribe, such as the White Water Lily (Fig. 629, p. 230), the Yellow Water Lily (Fig. 671), and in the Lotus (Fig. 667), this tendency is very evident. In Roses this transformation may be easily

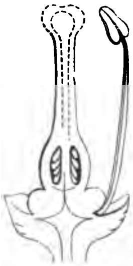

Fig. 669.

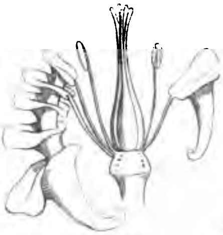

Fig. 670.

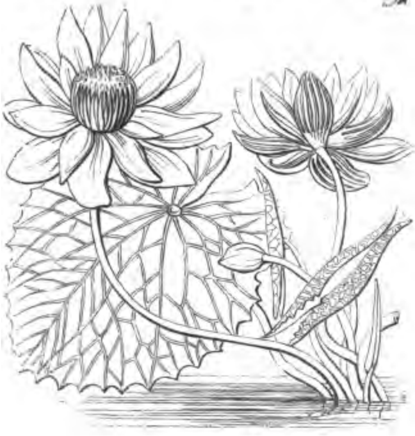

Fig. 667.

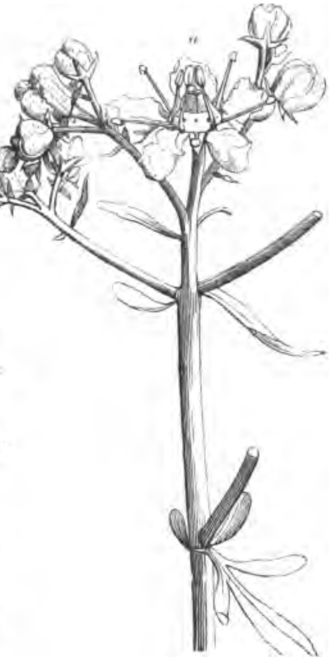

Fig. 668.

Fig. 667. The Lotus Water-Lily (*Nymphæa Lotus*), one of those plants in which there is a great tendency in the stamens to pass into petals. The leaves are beautifully reticulated. The plant is supposed to be the *Shushan* and *Shushannah* of the Old Testament, translated Lily (1 Kings vii. 19, 22, 26. 2 Chron. iv. 5. Cant. ii. 1, 2, 16; iv. 5; v. 13; vi. 3. Hos. xiv. 5).

Fig. 668. Flowering branch of Rue (*Ruta*), showing at *a*, the pistil dividing into separate parts, with a large circular disk at its base marked with dots. The petals are hooded at their extremities. It is the *Peganon* of the New Testament, translated Rue in Luke xi. 42.

Fig. 669. Pistil and receptacle of the Orange (*Citrus Aurantium*), cut vertically, showing the prominent part of the ring-like disk between the stamen and the ovary.

Fig. 670. Flower of Columbine (*Aquilegia vulgaris*), showing the conversion of stamens into folded petals, which are developed so as to form a series of horn-like tubes inserted within each other.

traced (Fig. 429, p. 181), as well as in all double flowers. In the case of Columbine the change is effected in such a way that the horned petals enclose each other (Fig. 670). Occasionally the petals are replaced by stamens. This kind of metamorphosis is much rarer than the opposite one. In Monandra fistulosa the lower lip is sometimes prolonged into a filament bearing an anther, and the petals of Shepherd's Purse have been observed antheriferous (anther-bearing.)

312. When the anther is abortive the filament sometimes produces hairs in its place. In the case of Canna, where only one anther lobe is perfected, the filament becomes petaloid. It is probable that the peculiar gland-like scales of Parnassia are only an altered state of the stamens (Fig. 570, p. 214). Goeppert noticed a specimen of Papaver officinale in which the anthers were converted into carpels. The conversion of the carpels into stamens is rare. Gay saw one of the styles of Colchicum antheriferous, and the other two prolonged into thread-like forms. Berkeley mentions a case of a white seeded Gourd, in which the pollen was replaced by ovules, many of them apparently perfect.*

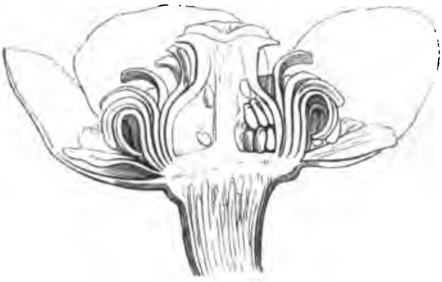

Fig. 671.

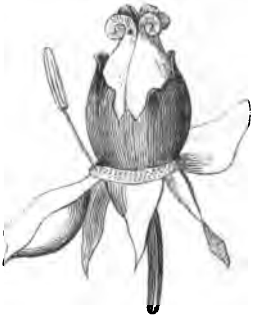

Fig. 672.

313. The organ which botanists call the *Disk*, seems to be in many cases an alteration of some of the staminal whorls. This is more especially true of such cases as Gloxinia and Gesnera, where the scales alternate with the developed row of stamens, and where the fifth stamen assumes the form of a scale. The Disk may be said to consist essentially of processes arising from the thalamus between the developed stamens and pistil. In the Orange (Fig. 669) the disk is in the form of a ring surrounding the base of the pistil; so also in Rue (Fig. 668), where it is very large and conspicuous. In the Vine (Fig. 571, p. 215), the disk-scales are evident. In the White Water

Fig. 671. Vertical section of the flower of the Yellow Water-Lily (*Nuphar luteum*), in which the stamens have a tendency to assume the form of petals. They are indefinite, and are attached below the pistil which occupies the centre.

Fig. 672. Flower of Tree Pæony (*Moutan officinalis*), deprived of its corolla, and showing the disk in the form of a fleshy expansion covering the ovary.

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* See Gardener's Chronicle, Aug. 9, 1851.

Lily the disk is a large cellular prolongation covering the ovaries (Fig. 629, *d*, p. 230). In the Tree Pæony (Fig. 672) it forms a dark red expansion which covers the follicles. In umbelliferous plants (Fig. 347, p. 148), the remains of the disk are seen at the upper part of the fruit.

314. Recapitulation of the general facts relative to the stamens:—

1. The Stamens are the third whorl of the complete flower, and are arranged in one or more alternating rows. They constitute the Andrœcium, or male organs.
2. They consist essentially of metamorphosed leaves, and follow the same law of development and arrangement that leaves do. In double flowers they are converted into petals.
3. In Monœcious, Diœcious, and Polygamous plants, some flowers have stamens without the pistil, and are called Staminiferous, Staminate, or male.
4. The stamens arise normally from the thalamus, but they undergo changes by adhesion to the calyx, corolla, and pistil.
5. They are attached to the thalamus, or, in other words, are Hypogynous in the plants included under the division of Thalamifloræ; to the calyx, or Perigynous, in Calycifloræ; to the corolla in Corollifloræ; and to the pistil in Gynandrous plants.
6. Each stamen consists usually of two parts—the Filament, and the Anther containing the fertilizing powder called Pollen.
7. The stamens are either free or united to each other. The union takes place by the filaments in Monadelphous, Diadelphous, and Polyadelphous plants; and by the anthers in Syngenesious plants.
8. Stamens exhibit, in many instances, variations in their relative lengths, and, in the case of Didynamous and Tetradynamous plants, these variations are in definite proportions.
9. Alterations take place in the stamens by abortion and degeneration of parts, by irregular growth and adhesion, and by chorisis.
10. The organ called the Disk is frequently an undeveloped condition of a Staminal row.
11. The Pollen consists of cells contained in the anther-case, and discharged by various kinds of longitudinal, transverse, valvular, and porous dehiscence.
12. In the development of pollen, the division into four is common, and the grains often continue united in fours or multiples of four.

B. *Gynœcium or Pistilline Organs.*

a. PISTIL BEFORE BECOMING THE FRUIT.

315. The pistil is the verticil which terminates the axis of growth, and is placed in the centre of the flower (Figs. 673 and 674). It is composed of leaves called *Carpels* or *Carpidia*, from their connection with the fruit. These leaves are folded, so that their lower surface is external, and they are well seen in the Cherry, with double flowers, in which the organs of reproduction are more or less completely altered. In this plant one or more leaves (Figs. 675 and 676) occupy the place of the pistil. In the monstrosity of the Rose, represented in Figure 426, p. 178, the pistil is changed into a series of alternate leaves. When there is a single carpel (Fig. 677), the pistil is *simple*, and the two terms (carpel and pistil) are synonymous; when there is more than

one carpel, the pistil is *compound* (Fig. 678). The carpels are either distinct or united; and it frequently happens, that by adhesion and obliteration, changes take place by which the number of the carpels is diminished, so that they do not equal the other whorls. It is rare to find the parts of the pistilline whorl symmetrical with the others. A flower,

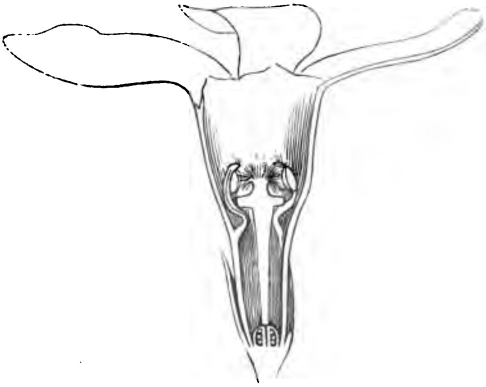


Fig. 673.

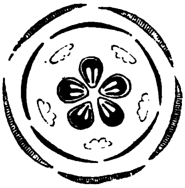


Fig. 674.

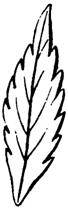
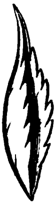


Fig. 675.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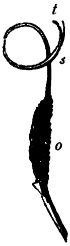

Fig. 677.

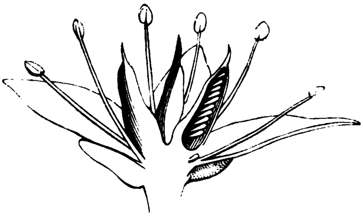
Fig. 678.

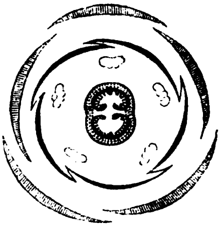
Fig. 679.

Fig. 673. Flower of Periwinkle (*Vinca*), cut vertically, showing the gynœcium in the centre, consisting of ovary, with ovules at the lower part, ending in the style and stigma. The latter is contracted like an hour-glass in the middle, and has two projecting parts below like a cross. The stamens are seen attached to the corolla.

Fig. 674. Ideal section of a regular, symmetrical, pentamerous flower. There are five parts of the calyx, five of the corolla, five stamens, and five carpels in the centre, forming the pistil. The carpels contain ovules or young seeds.

Fig. 675. Expanded carpellary leaf from the double-flowering Cherry.

Fig. 676. Folded carpellary leaf of the double-flowering Cherry. In place of fruit the plant produces leaves.

Fig. 677. Pistil of Broom, consisting of ovary, *o*, style, *s*, and stigma, *t*, It is formed by a single carpel. The terms pistil and carpel are here synonymous.

Fig. 678. Flower of Stone-crop (*Sedum*), cut vertically, showing three of the carpels forming the pistil in the centre. The pistil is compound, and as it consists of separate carpels, it is apocarpous or dialycarpous.

Fig. 679. Diagram of the flower of Tobacco (*Nicotiana Tabacum*). There are five divisions of the calyx and corolla, five stamens, and a dimerous pistil. The pistil is formed by two carpels or carpidia united, and is called syncarpous. The flower is symmetrical and pentamerous, although the pistil does not correspond with the other whorls in number.

however, is still called symmetrical if the numbers of the three outer whorls are equal to, or multiples of each other (¶ 245). Thus, the flower of Solanaceæ is symmetrical, in which the calyx, corolla, and stamens are pentamerous, while the full-grown pistil is dimerous (Fig. 679).

316. A pistil is called *apocarpous* or *dialycarpous* when all the carpels are separate (Figs. 680 and 681); and *syncarpous* when they are combined into one (Fig. 682). The parts of a perfect pistil, as already noticed in ¶ 229, are the *ovary*, containing ovules or rudimentary seeds, the *style*, and the *stigma*. These terms are rather vaguely used, as applying either to the parts of a single carpellary leaf, or to the parts of a pistil formed of more than one carpel, and in which the ovaries, styles, and stigmas are united completely. In Figure 683, the lower portion is the ovary containing the ovule, *ov*, the style is marked *tc*, and the stigma *st*. The style is not always present, and, when absent, the stigma is sessile, as in the Poppy (Fig. 417, *sti*, p. 175).

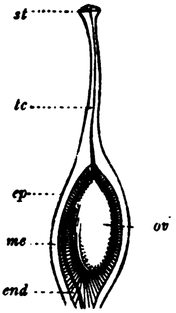

Fig. 683.

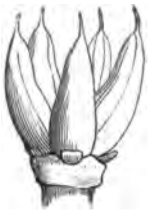

Fig. 680.

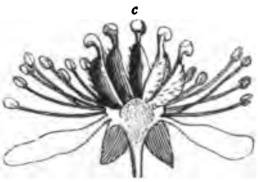

Fig. 681.

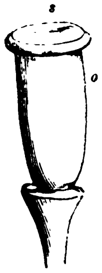

Fig. 682.

317. The ovary of a simple pistil consists of the folded blade of a

Fig. 680. Pistil (gynœcium) of Stonecrop (*Sedum*.) It consists of five carpels, which are separate and distinct. Each carpel has its own ovary, style, and stigma. The pistil is apocarpous or dialycarpous. At the base of the carpels are seen scales which are probably separated from the stamens by chorisis. These scales are called the nectary. Below the pistil is the part of the receptacle to which the other whorls were attached.

Fig. 681. Vertical section of the flower of Meadow-sweet (*Spiræa*). The pistil is apocarpous, consisting of several distinct carpels, *c*, each with ovary, style, and stigma. The stamens are indefinite, and inserted into the calyx.

Fig. 682. Pistil of the Barberry (*Berberis vulgaris*). It is syncarpous, consisting of several carpels combined. The stigma, *s*, is peltate (shield-like), and nearly sessile. The combined ovaries, *o*, end in a very thick and short style. Below the pistil is the receptacle or thalamus which bears the floral whorls.

Fig. 683. Pistil of Apricot (*Prunus Armenaica*), cut vertically. The solitary ovule, *ov*, is contained in the ovary, which consists of three coats, the inner, *end*, which corresponds to the upper epidermis of the carpellary leaf, and which finally becomes the hard stone of the Apricot. The middle, *me*, corresponding to the mesophyllum or parenchyma of the carpellary leaf, and which ultimately becomes the fleshy part of the Apricot; and the outer, *ep*, corresponding to the lower epidermis of the carpellary leaf, and which finally constitutes the separable skin of the Apricot. The style is prolonged upwards, containing a canal, *tc*, and ending in the stigma, *st*, consisting of loose cellular tissue uncovered by epidermis.

single leaf (Fig. 688), and resembles it in structure. The outer surface of the ovary (Figs. 683 and 688, *ep*) represents the lower epidermis of the leaf, sometimes covered with hairs, and, when green, exhibiting stomata; the inner surface (Fig. 683, *end*, and 688, *en*) represents the upper epidermis; between these two surfaces are placed the parenchyma, and the vascular tissue consisting of woody, spiral, and dotted vessels of various kinds (Fig. 683, *me*). The midrib is on the outer or dorsal surface, and therefore is inferior, while the two edges of the leaf (Fig. 688, *pl*) are united at their inner part or *face* next the axis, and are superior.

318. The face of the ovary is called the *ventral suture*, while the back is called the *dorsal suture*. At the ventral suture there is a cellular growth called the *placenta* (Fig. 688, *pl*), to which the ovules, *ov*, are attached often by a distinct cord, *f*. As each margin of the folded leaf or carpel forms a placenta, this organ is essentially double, and it sometimes shows its formation by appearing as two lamellæ (Fig. 688, *pl*). Along the placenta the ovules are placed in one or more rows (Fig. 685). Sometimes they occupy a small part of the placenta, as in cases where they are reduced to one (Fig. 683) or two. The parenchymatous tissue sometimes becomes hard, as in the nut; at other times it is much developed, and forms a succulent covering, as seen in fleshy fruits (Fig. 683, *me*).

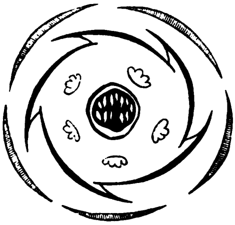
Fig. 684.

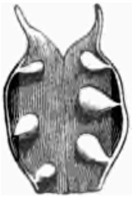
Fig. 685.

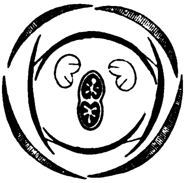
Fig. 686.

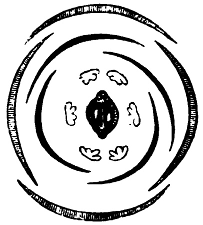
Fig. 687.

319. When the style exists, it is a prolongation of the cells and vessels of the leaf upwards, and represents the narrow portion of an acuminate leaf, folded so as to form a canal (Fig. 683, *tc*), with loose

Fig. 684. Diagram of the flower of the Gentian (*Gentiana*), consisting of five parts of the calyx, five of the corolla, five stamens, and two divisions of the pistil, which are placed laterally, *i. e.*, to the right and left of the axis. The flower is regular, symmetrical, and pentamerous. The pistil bicarpellary.

Fig. 685. One of the carpels forming the pistil of Meadow-sweet (*Spiræa*). It is laid open to show the ovules attached to the placenta on the ventral suture. The placenta, style, and stigma, are shown to be double.

Fig. 686. Diagram of the Flower of Speedwell (*Veronica*). There are four unequal divisions of the calyx and corolla, so that the flower is irregular; two stamens and two divisions of the pistil, one of which is superior, and the other inferior. The flower is unsymmetrical.

Fig. 687. Diagramatic section of the flower of Wallflower (*Cheiranthus Cheiri*). There are four parts of the calyx and of the corolla, six stamens, which are tetradynamous (four long in pairs, and two short), and a bicarpellary pistil, with the carpels placed laterally, *i. e.*, to the right and left of the axis. The division in the pistil consists of a prolongation of the placentas from either side, and is called a replum or frame.

cells inside. It is terminated by the stigma (Fig. 683, *st*), which is a loose cellular portion divested of epidermis, and moistened with fluid, so as to detain the pollen-grains when scattered. The stigma is sometimes a mere point, at other times it extends along one or both sides of the style. It is to be considered as continuous with the placenta.

320. When the pistil is formed of a single carpel (Fig. 677, p. 240), it terminates the axis, and appears to be continuous with it. When the pistil is bicarpellary, that is, formed of two carpels (Fig. 690), they are placed opposite to each other, and if they unite, it is by their ventral sutures. The carpels, in such a case, are usually placed so that one is superior, that is, next the axis, and the other inferior, next the bract of the axillary flower, as in the Figwort order (Fig. 686). Sometimes, however, they are lateral, that is, to the right and left of the axis in a plane at right angles to the axis and bract, as in the Gentian order (Fig. 684), and Cruciferæ (Fig. 687). When the carpels are more than two, they follow the usual laws of

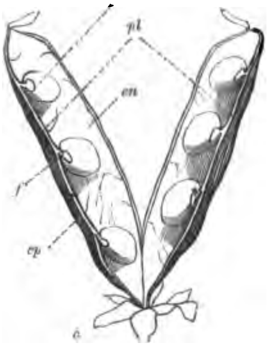

Fig. 688.

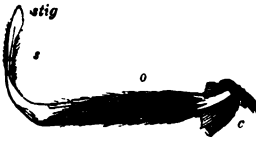

Fig. 689.

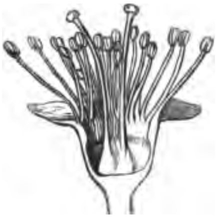

Fig. 690.

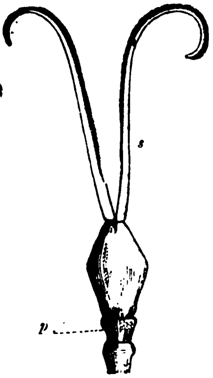

Fig. 691.

Fig. 688. Pistil of the Pea (*Pisum sativum*), laid open. It consists of a single carpel containing numerous ovules, *ov*, which are attached to the placenta, *pl*, or ventral suture in two rows, by means of umbilical cords (funiculi), *f*. The wall of the carpel consists of three layers, the outer, *cp*, corresponding to the lower epidermis of the leaf, the inner, *en*, corresponding to the upper epidermis of the leaf. Between these two layers there is a small amount of cellular tissue like the parenchyma of the leaf. The parenchymatous portion is not so much developed as in Figure 683. The calyx, *c*, is persistent. The style and stigma are marked *s*.

Fig. 689. Pistil of a kind of Sweet-pea (*Lathyrus*), formed by a single carpel, consisting of ovary, *o*, with a style, *s*, and stigma, *stig*. It is monocarpellary. The calyx, *c*, is persistent. The flower is monogynous, because it contains one carpel, and one style and stigma.

Fig. 690. Flower of Cherry (*Cerasus communis*), cut vertically, showing the pistil composed of two separate carpels (bicarpellary); only one of the carpels comes to perfection in the fruit. The flower is said to be digynous in this condition. The stamens are indefinite, and attached to the calyx. The plant belongs to the division Calycifloræ, and some call it calycandrous, on account of numerous stamens being attached to the calyx.

Fig. 691. Syncarpous pistil of Carnation (*Dianthus Caryophyllus*), consisting of two united carpels, supported on a stalk or podocarp, *p*, called also a thecaphore or gynophore. The two ovaries are united, but the two styles, *s*, are separate, with recurved extremities. The flower is therefore said to be digynous.

alternation with the other parts of the flower (Fig. 674, p. 240). It is chiefly in apocarpous pistils that the alternation can be satisfactorily seen; for in syncarpous pistils, the adhesion which takes place often obscures the arrangement.

321. The number of carpels in an apocarpous pistil, or the number of separate styles in a syncarpous one (*i.e.*, one in which the ovaries are united), is indicated in the following way:—

A flower with a simple pistil or one style				is Monogynous (Figs. 683 and 689).
A flower with two separate carpels or two separate styles				is Digynous (Figs. 690 and 691).
A flower with three	"	"	"	is Trigynous.
A flower with four	"	"	"	is Tetragynous.
A flower with five	"	"	"	is Pentagynous (Fig. 692).
A flower with six	"	"	"	is Hexagynous (Fig. 693).
A flower with seven	"	"	"	is Heptagynous.
A flower with eight	"	"	"	is Octogynous.
A flower with nine	"	"	"	is Enneagynous.
A flower with ten	"	"	"	is Decagynous.
A flower with twelve	"	"	"	is Dodecagynous.
A flower with a greater number		"	"	is Polygynous (Figs. 694 and 695).

These differences are employed by Linnæus in forming some of his Orders.

322. In an Apocarpous pistil, the carpels may be arranged in one circle (Fig. 693), or in several (Fig. 694). In the latter case, the inner whorls alternate in succession with the outer. Sometimes they are placed on a flattened receptacle or thalamus, as in Marsh Marygold; at other times on an elevated one, as in the Crowfoot (Fig. 694), in the Strawberry (Fig. 695), and in the Tulip-tree; while at other times they are placed on a concave one, as in the Rose (Fig. 696).

323. In a Syncarpous pistil, various degrees of adhesion take place. The carpels may unite merely at their inner angles, leaving marked external divisions, as in the Rue (Fig. 668, p. 237); or the ovaries may be completely united while the styles are separate, as in Lychnis (Fig. 697) and Nigella (Fig. 698); or the whole may be consolidated into one, as in the Primrose (Fig. 699). In rare cases, the styles and stigmas are united into one body, while the ovaries are separate, as in Labiatæ (Fig. 701) and the Borage order (Fig. 700), as well as in Asclepias.

324. In syncarpous pistils, the number of carpels entering into their composition may be traced by observing the grooves or lobes of the ovary, by the number of styles and stigmas, and, when complete union takes place, by the venation, or by the divisions seen in the interior of the ovary. Thus, in the Lily, the syncarpous

pistil is composed of three carpels united, and, by cutting across the ovary (Fig. 702), we observe three loculi containing ovules. The carpels are generally united in such a way, that partitions or dissepiments (septa), more or less complete, are seen on making a transverse section. These are formed by the union of the margins or sides of the carpellary leaves, each septum being essentially double or composed of the laminæ of two contiguous carpels. This is seen in the figure of the pistil of Colchicum (Fig. 703), which is formed by three carpels; and on making a transverse section (Fig. 704), the formation of the septa is evident. The septa of collateral carpels are therefore vertical, and equal to the number of carpels. There can be no true septum in a single carpel (Fig. 688, p. 243), but spurious divisions (phragmata) may be formed, either in a transverse manner by cellular processes proceeding from the walls of the carpel, as in Cassia Fistula (Fig. 705) and Desmodium; or in a vertical manner, by projections from the dorsal suture, as in Flax (Fig. 706); or by prolongations of the placenta, as in Cruciferæ, where a replum is produced (Figs. 707 and 708); or by a turning inwards of the ventral suture (Fig. 709), as in some species of Oxytropis, or of the dorsal suture, as in Astragalus (Fig. 710). In the Thorn Apple, the ovary, when cut transversely at the upper part, shows two cavities (Fig. 711); but when the section is made at the lower part of the ovary,

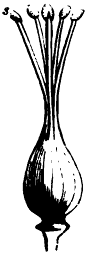

Fig. 692.

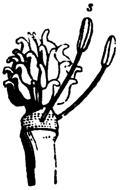

Fig. 694.

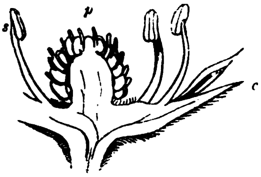

Fig. 695.

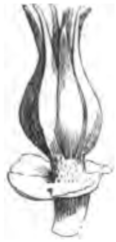

Fig. 693.

Fig. 692. Syncarpous Pistil of Flax (*Linum*). It consists of five carpels, united by their ovaries, while their styles and stigmas, *s*, are separate. Hence, the flower is pentagynous. On making a section of the compound ovary five loculaments are seen.

Fig. 693. Apocarpous pistil of Hellebore (*Helleborus*), consisting of six distinct carpels. The flower is hexagynous. Below the pistil is seen the receptacle or thalamus into which the other floral whorls are inserted. The plant belongs to the Thalamifloræ.

Fig. 694. Apocarpous compound pistil of Crowfoot (*Ranunculus*), consisting of numerous separate uni-ovular carpels, arranged in several rows on an elevated receptacle. The flower is polygynous. Each carpel consists of ovary, style, and stigma. Two of the stamens, *s*, are left to show their insertion below the pistil into the thalamus. The stamens are hypogynous, and the plant belongs to Thalamifloræ.

Fig. 695. Section of the flower of the Strawberry (*Fragaria vesca*), shewing the pistil in the centre, *p*, composed of numerous separate uni-ovular carpels, placed on an elevated portion of the receptacle, which ultimately becomes succulent, and constitutes what is commonly called the Fruit. Each carpel has a style and stigma. The flower is polygynous. Three of the stamens, *s*, are left to shew their insertion into the calyx, *c*. The stamens have introrse anthers dehiscing longitudinally. The plant belongs to Calycifloræ.

there are four cavities formed by a spurious vertical septum (Fig. 712).

325. When the partitions in the pistil extend to the axis, a transverse section shows a number of contiguous cavities or *loculaments* (loculi), with the placentas in the centre bearing ovules (Fig. 713).* A compound pistil of this sort composed of two carpels is two-celled (bilocular); of three, three-celled (trilocular), as seen in the Lily (Fig. 702), and Colchicum (Fig. 704); of four, four-celled (quadrilocular); of five, five-celled (quinquelocular), as in Campanula (Fig. 713); of many without distinct reference to number, many-celled (multilocular or plurilocular).

326. When the partitions do not extend to the centre, all the cells or loculi communicate, and hence such a compound pistil is really unilocular, or has one cavity, as in the Poppy (Fig. 717),

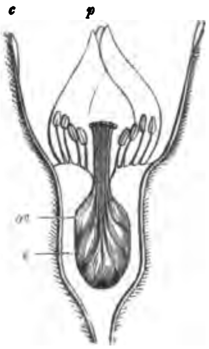

Fig. 696.

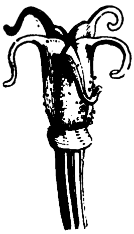
Fig. 698.

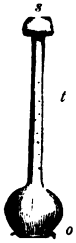

Fig. 699.

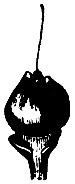
Fig. 700.

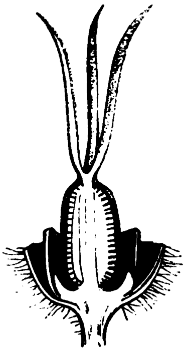
Fig. 697.

Fig. 696. Flower of the Rose (*Rosa*), cut vertically. The ovaries, *ov*, of the separate carpels are attached to a fleshy disk lining the calyx, *c*. The tube of the calyx is contracted at the upper part, and through the narrowed portion the styles pass. Each carpel has its ovary, style, and stigma, and contains a single ovule. The petals, *p*, as well as the stamens, are inserted into the calyx. The flower is polygynous. The plant belongs to Calycifloræ.

Fig. 697. Syncarpous pistil of Rose-campion (*Lychnis*), cut vertically. It is supported on a short stalk or gynophore. The ovaries are so united as to form one compound ovary, with one loculament. The ovules are attached to a free central placenta, owing apparently to a rupture of the dissepiments (septa). The styles are separate; three are seen in the figure. The flower is Pentagynous. The placenta in the centre of the compound ovary is very large.

Fig. 698. Compound syncarpous pistil of Nigella, consisting of five carpels partially united. The five styles and stigmata are free, and the flower is pentagynous. The divisions of the carpels are seen at the apex, and along the sides of the compound ovary.

Fig. 699. Compound syncarpous pistil of Primrose (*Primula*). The five carpels of which it is composed are completely consolidated so as to appear one. The ovaries, *o*, the styles, *t*, and stigmata, *s*, are united. The flower is called Monogynous, although in reality there are five parts of the pistil.

Fig. 700. The Pistil of Cerinthe, a plant of the Borage order. There are four carpels forming the pistil. The ovaries of the carpels are separate, while the styles and stigmas are united into one.

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* Some restrict the term placenta to the point where an ovule is attached, and give the name of placentary to the extended cellular body bearing more than one ovule. Several placentaries combined form what has been called the central placenta.

Reseda (Fig. 718), and Orchis (Fig. 719). In these unilocular syncarpous pistils there may be seen partitions proceeding to a greater or less extent into the cavity of the ovary, and bearing placentas on their edges (Fig. 715). Such placentas are called *parietal*, and their number indicates the number of united carpels. These placentas are sometimes nearly sessile on the walls of the ovary (Figs. 716 and 718); at other times they are supported on distinct parietal septa (Figs. 715 and 719). Such are called cases of parietal placentation, and are considered as showing the formation of *marginal* placentas, on the edges of carpellary leaves more or less completely folded inwards towards the axis. The ovules, in these instances, are analogous to buds on the margins of leaves, as seen in Bryophyllum (Fig. 720).

327. Cases occur in which the carpels are united so as to have no apparent folding inwards of their edges, and in which the placentas are placed in the centre, quite separate from the walls of the ovary,

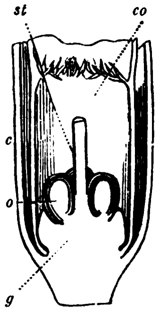
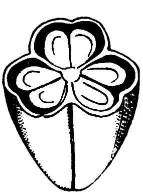


Fig. 701.



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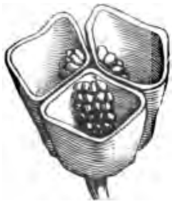
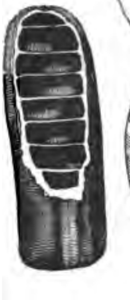


Fig. 704.



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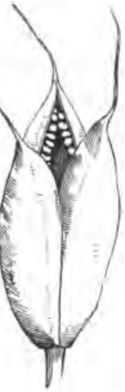


Fig. 703.

Fig. 701. Vertical section of part of the flower of Sage (*Salvia*), one of the Labiate plants. The calyx, *c*, corolla, *co*, the receptacle, *g*, the pistil in the centre, consisting of ovaries, *o*, and style, *st*. In this plant there are four carpels forming the pistil, two of which are seen in the figure. These carpels become separate, while the styles are united into one. The union of the carpels takes place by the styles, and not by the ovaries.

Fig. 702. Ovary or lower part of the pistil of the Lily (Lilium), cut transversely. There are three loculaments, indicating the union of three carpels, and the ovary is said to be trilocular. The divisions in the ovary, called septa or dissepiments, are formed by the sides of the carpellary leaves. Each septum is double, and the number of septa corresponds with the number of the carpels. The ovules are placed collaterally, in pairs, in each loculament, and are attached to a central placenta, formed by the union of the three ventral sutures.

Fig. 703. Pistil of Meadow-saffron (*Colchicum*), consisting of three carpels, which finally separate from each other at the apex, shewing the composition of the compound pistil. The dehiscence is called septicidal, because it takes place through the septa.

Fig. 704. The compound ovary of Meadow-saffron (*Colchicum*), cut transversely, shewing three loculaments, formed by the union of three carpels, which ultimately separate at the dissepiments. The ovules are attached to the placentæ in the centre.

Fig. 705. Pistil of Cassia Fistula (*Cathartocarpus Fistula*), cut vertically, showing the separate divisions in the legume. The divisions are spurious septa (phragmata), formed from the inner lining of the ovary. Each division contains a single seed, with pulp around it.

as in the Chickweed and Primrose families. This is called *central* placentation (Figs. 721 and 722). It is by some considered as being

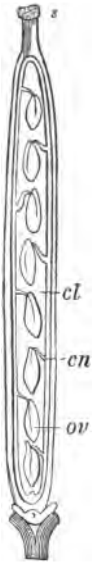


Fig. 707.

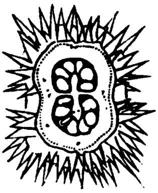


Fig. 711.

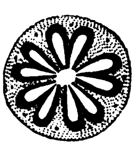


Fig. 706.

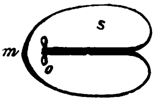


Fig. 709.

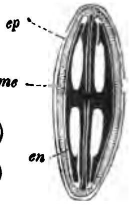


Fig. 708.

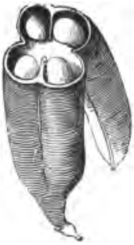


Fig. 710.

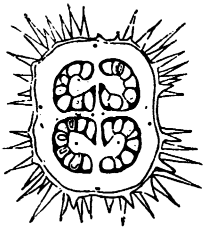


Fig. 712.

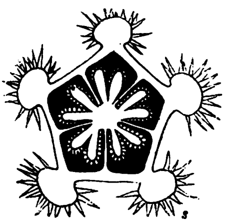


Fig. 713.

Fig. 706. Compound ovary of Flax (*Linum*), cut transversely, showing the five carpels of which the ovary is formed, and each of these carpels subdivided by foldings of the dorsal suture into two, thus making in all ten divisions. (See Fig. 692).

Fig. 707. Compound ovary (*Siliqua*) of Wallflower (*Cheiranthus*), consisting of at least two carpels united. One valve has been removed to show the partition or replum, *cl*, formed of a double layer from the placentæ, *cn*, on either side, to which the ovules, *ov*, are attached by means of funiculi. The ovules form a single row, one above the other, alternately attached to either side. The partition is spurious (phragma), as it is not formed by the edges of the carpels. The style and stigma, *s*, are at the upper part of the ovary.

Fig. 708. Transverse section of the pistil of the Wallflower (*Cheiranthus Cheiri*), showing the outer layer of the ovary, *ep*, the middle, *me*, and the inner, *en*. There are two divisions in the ovary, separated by a nearly complete phragma or spurious dissepiment, formed from the placentæ on either side, to which the ovules are seen attached by funiculi or umbilical cords.

Fig. 709. Diagram to illustrate the formation of a spurious septum in a carpel, by the folding inwards of the ventral suture. The midrib of the leaf, *m*, the inflected edges of the ventral suture, *s*, and the placenta, with the ovules, *o*. A unilocular ovary may thus become spuriously bilocular.

Fig. 710. Pistil of Milk-vetch (*Astragalus*), the ovary of which becomes spuriously two-celled (bilocular), by the folding inwards of the dorsal suture. The carpel is cut transversely across to show the partition and the ovules.

Fig. 711. Ovary of the Thorn-apple (*Datura Stramonium*), cut transversely at the upper part, showing two carpels united to form a compound ovary. The inner edges of each of the carpels, after meeting in the centre, turn outwards, and bear the ovules on their projecting portions.

Fig. 712. The ovary of the Thorn-apple (*Datura*), cut transversely at the lower portion, showing the mode in which the ventral sutures of each of the carpels turns outwards towards the midrib, whence a cellular prolongation proceeds, so as to divide the ovary into four in place of two loculaments. The partitions are spurious, and the ovary is spuriously quadrilocular, or tetrathecal.

Fig. 713. Ovary of Bell-flower (*Campanula*), cut transversely. The placenta is in the centre, consisting partly of a prolongation of the axis in the form of a column, and partly of the true placentaries, bearing numerous ovules, arranged collaterally in pairs. The ovary is quinquelocular, being formed by five carpels, which are attached to the calyx, *s*. The back of each of the carpels corresponds to the midrib, *s*, of a sepal.

produced by the disappearance of the septa, or by their rupture, at an early period of the growth of the ovary, so as to leave the placentas in the middle. This view is strengthened by seeing in some of the Chickweed tribe, septa in a very early stage of growth (Fig. 723, *c*), and imperfect remains of these partitions on the wall of the ovary, even in an advanced stage (Fig. 721). Berkeley, on examining a monstrous Carnation (a plant belonging to the Chickweed family), found that the placentation was at first marginal, and that, at an early period of growth, the placentas separated from the septa from the base upwards, forming a central solid mass below, but still bear-

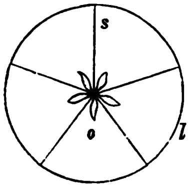
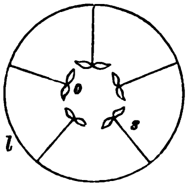


Fig. 714.



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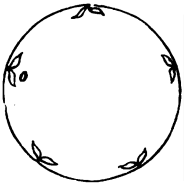

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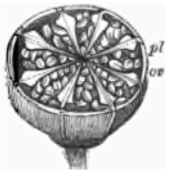


Fig. 717

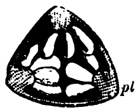
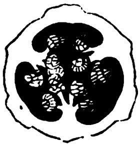


Fig. 718.



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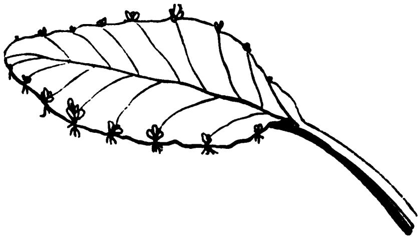


Fig. 720.

Fig. 714. Diagramatic section of a quinquelocular or pentathecal ovary, composed of five carpels, the edges of which are folded inwards, and meet in the centre. The ovules, *o*, are attached to a central placenta, formed by the union of the five ventral sutures. The five partitions, septa, or dissepiments, *s*, are composed of the two sides of contiguous carpels.

Fig. 715. Diagramatic section of a quinquelocular ovary, in which the septa, *s*, proceed inwards for a certain length, bearing the placentas and ovules, *o*. In this case the ovary is unilocular, and the placentas are parietal.

Fig. 716. Diagramatic section of a quinquelocular ovary, in which the edges of the carpels bearing the placentas and ovules, *o*, are not folded inwards. The placentas are parietal, and the ovules appear sessile on the walls of the ovary. The compound ovary is unilocular, and edges of its carpels are applied to each other in a valvular manner.

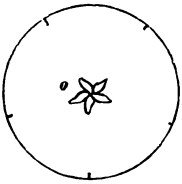
Fig. 717. Ovary of the Poppy (*Papaver*), cut transversely, showing the parietal placentaries, *pl*, the whole surface of which is covered by ovules, *ov*. The ovary is unilocular. Spurious placental divisions extend in the young state towards the centre. As the pistil advances to maturity the placentas become shorter.

Fig. 718. Unilocular or monothecal ovary of Mignonette (*Reseda*), cut transversely, showing the ovules attached to three parietal placentas, *pl*.

Fig. 719. Unilocular or monothecal ovary of an Orchid (*Orchis*), cut transversely, showing three parietal placentas bearing ovules. The edges of the carpels are slightly folded inwards.

Fig. 720. Leaf of Bryophyllum calycinum, with buds at the crenatures of its margin. These buds may be considered as representing ovules attached to marginal placentas. When such a leaf is folded upwards so that its margins meet, the buds are then in the situation of the ovules in a single carpel.

ing evidence of their original formation by their connection with the stigmas above.



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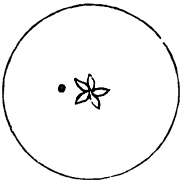

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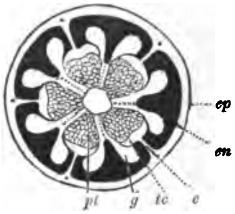
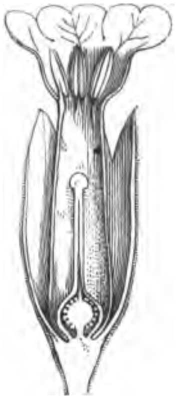


Fig. 723.



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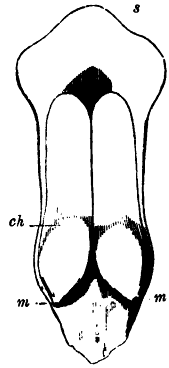


Fig. 725.

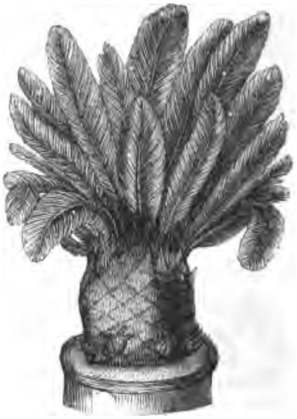


Fig. 726.

328. In some instances, however, especially in the Primrose tribe

Fig. 721. Diagramatic section of a compound unilocular ovary, formed by five carpels, the edges of which are very slightly folded inwards, as represented by short lines on the inner surface of the circle. The ovules, *o*, are in the centre, and not attached to the walls of the ovary. Such a case is supposed to be produced by the septa being ruptured and absorbed, so as to leave the placentas with the ovules in the centre. It may represent what takes place in the Chickweed order. Some consider the placenta in this case as being formed from the axis.

Fig. 722. Diagramatic section of a compound unilocular ovary, in which there are no indications of partitions. The ovules, *o*, are attached to a free central placenta, which has no connection with the walls of the ovary. This may represent what occurs in the Primrose order. In this case the placenta is said to be a truly axile, and not marginal formation.

Fig. 723. Young ovary of Rose-campion (*Lychnis*), cut transversely. In the centre is the axis, with five rays proceeding from it, dividing the placentas, *pl*, which are in connection with the conducting tissue, *tc*, of the styles, and which bear the ovules, *g*. In this young state there are five septa, *c*, extending from the walls of the ovary to the placenta. These partitions are finally ruptured, so that the placenta becomes free in the centre. The outer wall of the ovary is marked, *ep*, the inner, *en*. Some consider the placenta in this case as axile.

Fig. 724. Section of the flower of a Primrose (*Primula*), showing the pistil laid open. The round ovary is seen at the base of the style, containing numerous ovules attached to a free central placenta. The stigma is capitate. The stamens are attached to the upper part of the tube of the corolla, and opposite to its segments.

Fig. 725. One of the scales of a Fir-cone, bearing at its base two winged ovules. The base of the ovules or the chalaza is marked *ch*, the apex or micropyle, *m m*. The scale is looked upon as a modified bract, and the ovules are said to be naked, *i. e.*, not contained in a true carpel with ovary and stigma. The plant is gymnospermous, having naked ovules.

Fig. 726. False Sago plant (*Cycas revoluta*). It is one of the plants which produce naked ovules. It belongs to the natural order Cycadaceæ. A fine specimen, with ovules attached, is to be seen in the Museum at the Botanic Garden, presented by Dr. Gilbert M'Nab.

(Fig. 724), no vestiges of septa are found, and no marginal ovules at any period of growth (Fig. 722). Hence this kind of central placentation is supposed to be produced by a prolongation of the axis, and it

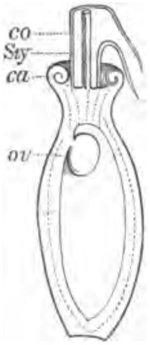


Fig. 727.

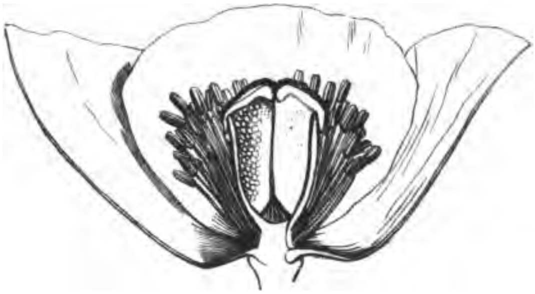


Fig. 729.

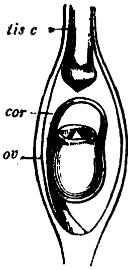
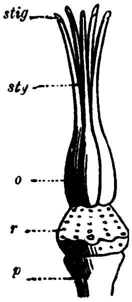


Fig. 728.



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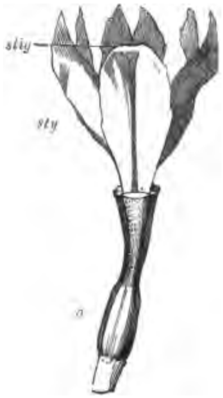


Fig. 732.

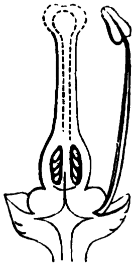


Fig. 731.

Fig. 727. Pistil of Red Valerian (*Centranthus ruber*), cut vertically, showing a single suspended ovule, *ov*, attached to the placenta near the summit of the ovary. The calyx, *ca*, is attached to the ovary, and its limb consists of incurved hairs; *sty* the style, and *co* part of the corolla.

Fig. 728. The ovary of the Sea-Pink (*Armeria*), cut vertically, showing the ovule, *ov*, with its coverings suspended by a cord or funiculus, *cor*, which rises from the basilar placenta. The conducting tissue of the style, *tis c*, passes for a certain way into the ovary.

Fig. 729. Vertical section of the flower of the Poppy (*Papaver*), showing numerous ovules attached over the surface of the placentary. The stigma is sessile on the top of the ovary. The stamens are numerous (indefinite) and hypogynous.

Fig. 730. Pistil of Columbine (*Aquilegia vulgaris*), situated on the receptacle, *r*, which is at the summit of the peduncle, *p*. The pistil is formed of five separate carpels, arranged in a circle on the receptacle. Each carpel consists of ovary, *o*, style, *sty*, and stigma, *stig*. The pistil is apocarpous.

Fig. 731. Pistil of Orange (*Citrus Aurantium*), situated above the calyx, and having a circular disk at its base. The pistil is superior, and it consists of a compound ovary, style, and stigma.

Fig. 732. Gynœcium of the Flower-de-Luce (*Iris*), consisting of an ovary, *o*, adherent to the perianth, and a style, *sty*, which divides into three petaloid segments bearing stigmas, *stig*. The ovary is inferior, and the perianth superior.

is therefore denominated *axile*—the leaves of the gynœcium being looked upon as united in a valvate manner, and as being verticillate round the placentary axis, which bears ovules like leaf-buds. Those who adhere to the view of all placentas being formed on the margins of leaves, have endeavoured to account for cases of *free central* placentation like those of the Primrose, by considering the placenta as formed by chorisis from the edge of carpellary leaves, or by placentas produced only at the base of the carpel, and, after uniting together in the centre, becoming elongated and enlarged. On the other hand, some advocates of axile placentation not only apply this view to such cases as those of the Primrose, but to all cases of placentation whatever; and, in the case of parietal placentas, think that the axis divides into a number of cellular prolongations, which become attached to the edges of the carpellary leaves.

329. Schleiden, who supports the view of axile placentation in all cases,* looks on the ovules as buds from the placental axis, or what he calls the spermophore. In the case of Coniferous plants, he says, that the scales of the cone are not bracts (¶ 206), but carpellary leaves (Fig. 725), and that the axis of the cone is the placenta giving off ovules or buds at different parts which are quite free from the carpels. He considers the cone, therefore, as supplying an argument in favour of his view of placentation. In the Yew, he views the ovule as the terminal bud of the axis. In the case of cone-bearing

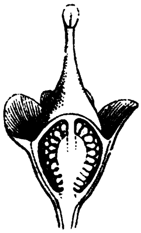


Fig. 734.

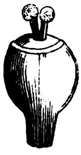
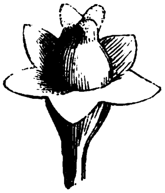


Fig. 733.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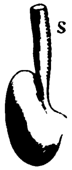

Fig. 736.

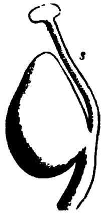

Fig. 737.

Fig. 733. Pistil of Madder (*Rubia*), with the calyx tube adherent to the ovary, and its limb appearing as a rim round the top of the ovary. There are two styles and stigmas. The ovary is inferior, and the calyx limb superior.

Fig. 734. Pistil and calyx of Saxifrage (*Saxifraga*), cut vertically, showing the calyx partially adherent to the ovary. The ovary is half-inferior, and the calyx half-superior. The compound ovary consists of two carpels containing numerous ovules.

Fig. 735. Pistil of the Elder (*Sambucus*), with the ovary partially adherent to the tube of the calyx, and surmounted by three sessile stigmas. The ovary is said to be half-inferior, and the calyx half-superior.

Fig. 736. One of the carpels forming the pistil of the Strawberry (*Fragaria vesca*). The carpel contains one seed, and it has a lateral style, *s*. The style arises from the true organic apex, which is so turned round as to appear on the side of the carpel.

Fig. 737. Uni-ovular carpel of Lady's-mantle (*Alchemilla*), with the style, *s*, arising from the apparent base. It is called a basilar style, although it arises from the organic apex which is here turned round. The stigma at the summit of the style is capitate.

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* See Schleiden's Principles of Botany, translated by Lankester, p. 382.

plants such as the Fir (Fig. 172, p. 72), as well as in the Cycas family (Fig. 726), the ovules are generally called naked, because they are not considered by authors as being enclosed within a true pistil furnished with a stigma. The scales of Conifers, which are either dry, as in the common Fir, or succulent, as in the Juniper (Fig. 273, p. 121), are thus looked upon by some as bracts, and by others as expanded carpellary leaves, each producing a placenta at its base, to which the ovules are attached. The plants are usually called *naked-seeded* (Gymnospermous).

330. Marginal placentas are formed either by the edges of a single carpel (Fig. 688, p. 243), or by the edges of two contiguous carpels. The former takes place in apocarpous pistils (Fig. 680, p. 241), and in syncarpous pistils with complete septa (Fig 704, p. 247); the latter in syncarpous pistils with parietal placentas (Fig. 719, p. 249). The placenta does not always bear ovules throughout its whole extent. Sometimes it is *ovuliferous* (ovule-bearing) only at or near its summit (Fig. 727), or in its middle or at its base (Fig. 728). In such placentas, the ovules are sometimes reduced to one, as in the Common Sea Pink (Fig. 728), and in Composite plants (Fig. 542, p. 208). The placenta, in some instances, extends from the margin of the carpellary leaves over the whole inner surface of the ovary, as in the Flowering Rush, in the White Water Lily, and in the Poppy (Fig. 729). The spreading of the placenta over the surface may give rise to the appearance of ovules proceeding from the dorsal suture, especially when that is the only part of it which bears ovules.

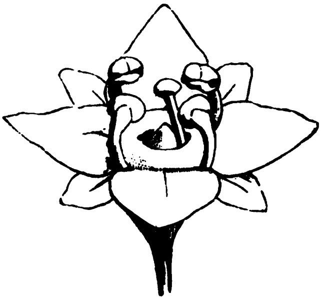


Fig. 738.

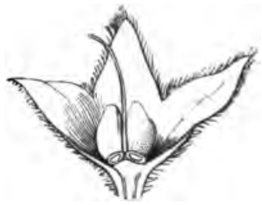


Fig. 739.

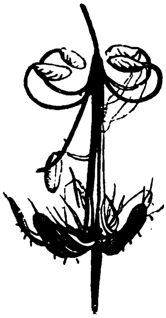


Fig. 740.

Fig. 738. Tetramerous flower of Lady's-mantle (*Alchemilla*). The pistil in the centre shows a style which does not arise from the apparent summit of the ovary, the point of which is seen projecting beyond the hard ring at the throat of the calyx. There are four parts of the calyx, and four of corolla, and four stamens.

Fig. 739. Calyx and pistil of the Comfrey (*Symphytum*), cut vertically. The pistil consists of four carpels, the ovaries of which are free, while the compound style appears to arise from the axis in consequence of being basilar. Each ovary contains a single ovule. Two ovaries have been removed.

Fig. 740. Pistil of Crane's-bill (*Geranium*), consisting of five carpels, attached by their styles to a long beak-like prolongation of the axis. The styles ultimately separate from the axis, as represented in the figure, and the ovaries curl upwards.

331. The carpellary leaves forming the pistil or Gynœcial verticil are usually sessile (Fig. 741), but cases occur in which they appear to be stalked, so as to raise the ovary. Such an occurrence may be considered as depending either on a prolongation of the axis supporting the pistil, as seen occasionally in certain monstrosities of Rose (Fig. 426, p. 178) and of Geum, or on the union of the petioles of carpellary leaves. In the Passion-flower, there is a distinct stalk or gynophore bearing the pistil. The same thing takes place in some of the Caper tribe (¶ 231), as well as in Lychnis (Fig. 697, p. 246) and in the Pink (Fig. 691, p. 243), where the stalk is short and thick.

332. When the pistil is free in the centre of the flower, it is called *superior*, and the other verticils are inferior or hypogynous (Fig. 731). It is often united to the calyx and the other whorls. When the adhesion between the ovary and calyx or perianth is complete, as in the Gooseberry, Currant, Madder (Fig. 733), and Iris (Fig. 732), the ovary is said to be inferior. In such instances, the petals and stamens, which are attached to the calyx, appear to arise from the summit of the ovary, and are called *epigynous*. Between these two conditions, there are intermediate stages of adhesion, as in Saxifrage (Fig. 734) and Elder (Fig. 735), where the ovary becomes half-inferior.

333. In certain cases, it has been supposed that the axis forms part of the walls of the ovary by spreading out in a concave manner, in the same way as the expanded axis of Eschscholtzia seems to form part of the calyx. In the Rose, the axis becomes united to the tube of the calyx (Fig 425, p. 178), and is prolonged so as to form a hollow cavity or disk, on the inside of which numerous separate carpels are placed.

334. The style is the prolonged apex of the carpellary leaf, and is not an essential part of the pistil. In some cases it seems to be a process from the placenta, as shown by Lindley in Babingtonia. It may, therefore, consist merely of cellular tissue, with spiral vessels, or it may also have woody tubes, and other vessels of the midrib and blade of the leaf entering into its composition. A canal traverses it (Fig. 683, *tc*), containing loose cells, called *conducting tissue*, which is continuous with the placenta. The style (Fig. 741, *s*) is situated at the proper apex of the leaf (*apicilar*), but, by changes in the direction of the apex, it frequently happens that the style appears to be *lateral*, as in the Strawberry (Fig. 736), or even *basilar*, *i.e.*, from the apparent base, as in Lady's-mantle (Figs. 737 and 738). In syncarpous pistils, the styles are frequently united, so as to appear single (Figs. 699, p. 246, and Fig. 741). When the carpels are placed round an enlarged axis, so that their apices are united to the summit of it, the styles, when united, appear to come from the axis of the plant, as in many of the Borage order (Fig. 739), and in the Sage (Fig. 701, p. 247). The carpels are called in such cases *gynobasic*. In the Geranium the styles are united to the prolonged axis or beak, from which they separate when the fruit is ripe (Fig. 740).

335. The style in its form is generally rounded, but at times it becomes flat, like a petal, as in Indian-shot. In the Bell-flower there are peculiar hairs on the style (Fig. 742), apparently connected with the application of pollen. The style in the pistil of Clematis is also hairy, so as to render the fruit *caudate* or tailed (Fig. 743). A style, apparently simple (Fig. 739), may be formed of several united. Frequently the divisions of such a style extend downwards for a certain length, showing the parts of which it is composed, and thus indicating the number of carpels (Fig. 692, p. 245, and Figs. 744, 745, and 746). But there are cases in which the style, proceeding from a carpel, actually splits into two parts, becoming *forked*, as in Euphorbia (Fig. 747, *s*). This splitting is accounted for by the circumstance that the style is in reality double, formed of two sides of the leaf (Fig. 685, p. 242).

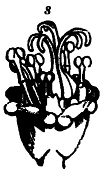
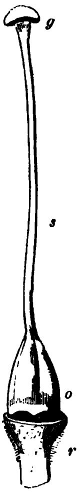


Fig. 747.



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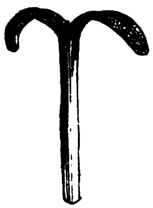
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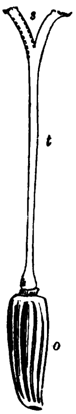

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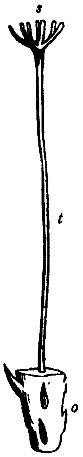

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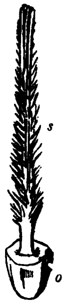

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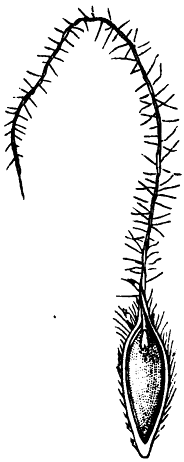


Fig. 743.

Fig. 741. Syncarpous pistil of Tobacco (*Nicotiana Tabacum*), consisting of two united carpels. The pistil exhibits the compound ovary, *o*, the long style, *s*, and the capitate stigma, *g*. The end of the peduncle is marked, *r*.

Fig. 742. Pistil of Bell-flower (*Campanula*), consisting of a compound ovary, *o*, adherent to the calyx, a compound style, *s*, with hairs on its surface to collect the pollen, and a five divided stigma at its apex.

Fig. 743. One of the carpels forming the pistil of Traveller's-joy (*Clematis*). The ovary contains a single ovule, and the style is feathery. The carpel has been called caudate.

Fig. 744. Style of a ligulate flower of Milfoil (*Achillea*), it splits into two at its apex, bearing a stigma on each division.

Fig. 745. The pistil of Ox-eye (*Chrysanthemum*), consisting of ovary, *o*, adherent to the tube of the calyx, and surmounted by the obsolete limb of the calyx, the style, *t*, splitting at its apex, *s*, so as to bear two stigmatic surfaces. There are hairs on the divisions of the style, and tufts of hairs at the stigmas.

Fig. 746. Pistil of a species of Indian-fig (*Cactus*), consisting of a compound ovary, *o*, adherent to the calyx, a long style, *t*, which divides at the apex, into several parts bearing stigmas, *s*.

Fig. 747. Involucre of a species of Spurge (*Euphorbia*), containing numerous male, and one female flower. The latter consists of a trilocular ovary, surmounted by three forked styles, *s*.

336. The stigma is a part of the pistil, composed of loose cells, which secrete a viscid fluid, and which are uncovered by epidermis. This organ is either sessile on the summit of the ovary, as in the Tulip and Poppy (Fig. 417, p. 175), or it is placed at the apex (Fig. 741, *g*), or on the side of the style. It may be said to be continuous with the placenta, differing from it in not bearing ovules. This connection with the placenta is evidently seen in cases where it can be traced along one or both sides of the style as far as the ovary. Being formed like the placenta, it is essentially double, and sometimes

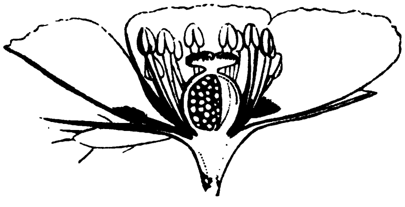
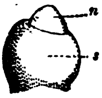


Fig. 748.



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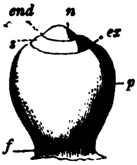


Fig. 755.

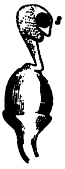


Fig. 750.

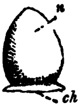


Fig. 751.

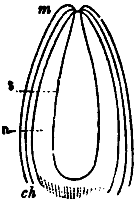
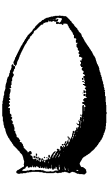


Fig. 752.



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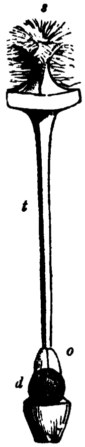

Fig. 749.

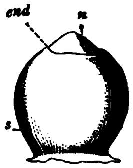

Fig. 756.

Fig. 748. Vertical section of the flower of the Rock-rose (*Helianthemum*). The pistil is seen consisting of a compound ovary, containing numerous ovules, and surmounted by a short style, and a shield-like (peltate) stigma. The stamens are indefinite and hypogynous.

Fig. 749. Pistil of the Periwinkle (*Vinca*), consisting of ovary, *o*, style, *t*, and stigma, *s*, which is covered with hairs, and exhibits a peculiar hour-glass contraction in its middle, with a large circular rim below. At the base of the ovary is a peculiar disk, *d*.

Fig. 750. Pistil of the Pansy (*Viola tricolor*). It consists of ovary, style, and a peculiar hooded and hooked stigma, *s*, with a marked hole, as represented by the dark round spot.

Fig. 751. Young ovule of Celandine (*Chelidonium majus*) before its coverings are developed. It consists of the nucleus, *n*, which at this stage of growth is naked. The base of the nucleus, where the nourishing vessels enter, is marked *ch*. This point is called the chalaza.

Fig. 752. Orthotropous or Orthotropal ovule of Polygonum, showing the embryo sac, *s*, in the nucleus, *n*, the different ovular coverings, the base of the nucleus or chalaza, *ch*, and the apex of the ovule with its foramen, *m*.

Fig. 753. The ovule of the Mistleto (*Viscum album*). It consists of a naked nucleus, at the apex of which a depression appears, and ultimately a cavity, which is the sac of the embryo.

Fig. 754. The ovule of Celandine (*Chelidonium*), showing the nucleus, *n*, partially covered by the secundine, *s*.

Fig. 755. The ovule of Polygonum, with its nucleus, *n*, covered by the inner coat, *s*, or the secundine, and the outer coat, *p*, or the primine. The opening in the secundine, *end*, is called the endostome, that in the primine, *ex*, is the exostome. The point of the nucleus is seen projecting at the foramen. The end by which the ovule is attached to the placenta is marked, *f*.

Fig. 756. Ovule of the Walnut (*Juglans regia*), with a single coat, *s*, covering the nucleus, *n*, The foramen is marked *end*.

shows a division on one side, as in Drosera and some Euphorbias (Fig. 747, *s*). The half of one stigma occasionally unites to the half of that next it, thus giving rise to a peculiar abnormality in the relation of the parts.

337. Stigmas in a syncarpous pistil are either united (Fig. 699, *s*, p. 246) or free (Fig. 692, *s*, p. 245). In the latter case, their lobes or lamellæ indicate the number of carpels (Figs. 744, 745, and 746, *s*). The united stigmas sometimes become large and orbicular, as in Rock-rose (Fig. 748), or capitate, as in Primrose (Fig. 699, *s*, p. 246), or they radiate along a shield-like body, as in the Poppy (Fig. 417, *sti*, p. 175). In the Periwinkle (Fig. 749), the stigma is covered with hairs, and exhibits a marked contraction in the middle like an hour-glass, with a broad rim below. In the Nettle (Fig. 575, *s*, p. 216), the stigma is covered with hairs radiating from a point, and is called penicillate. In the Violet (Fig. 750, *s*), the stigma has a hooded and hooked appearance.

338. The name of stigma is sometimes erroneously given to parts of the style. Thus the upper petaloid portions of the style of the Iris (Fig. 732, *sty*, p. 251) have been called stigmata, a term which ought to be restricted to the little slits at their apex (Fig. 732, *stig*, p. 251). So also the umbrella-like stigma of Sarracenia is in reality an expansion of the styles with the stigmata at their edges. In some stigmata, as those of Mimulus, the two lamellæ are irritable, and close when touched. In Orchids (Fig. 616, p. 228), the stigma is sessile on the common column (gynostemium), and appears as a viscid space immediately below the anther lobes.

339. *Transformations of the Pistil* are of frequent occurrence. They depend, generally, on abortion of a certain number of carpels and adhesions of various kinds. In the apocarpous pistils of Aconite, Nigella, Larkspur, and Pæony, we find on the same plant pistils composed of two, three, four, five, and six carpels. In some of the Brambles, Moquin-Tandon has seen all the carpels except one disappear, thus making the fruit resemble that of the Plum. In the case of Leguminous plants, there is usually only a single carpel, although the flower is pentamerous; this state has been traced to abortion of carpels, and the view is confirmed by finding plants in the same natural order with more than one carpel. Thus, in the genus Diphaca there are two, so also in Cæsalpinia digyna, while in Affonsea there are five. The pistil of the Almond, Cherry (Fig. 690, p. 243), Plum, and Peach, primarily consists of two carpels, one of which usually becomes abortive. Pistils of a succulent nature, such as those of the Sloe and Bird-cherry, sometimes assume the form of a pod, like that of the Pea. Occasionally stamens are changed into carpels, as in Papaver bracteatum, according to Turpin; and at other times, as in Colchicum according to Gay, the carpels are transformed into stamens, and bear pollen.

340. *The Ovule* is the rudiment of the future seed (Fig. 683, *ov*, p.

241), and in its early state it appears as a minute cellular projection or mammilla of the placenta. It is analagous to a bud produced by the edge of a leaf, as in Bryophyllum (Fig. 720, p. 249), or to a bud formed on a branch in cases where the placenta is axile. The cells multiply until the ovule assumes a more or less enlarged ovate form, constituting what has been called the *nucleus*, or the central cellular mass of the ovule (Fig. 751). The term nucleus must not be confounded with the nucleus of a cell (Fig. 42, p. 22, and ¶ 58).

341. The ovular nucleus alters in the progress of growth, so as to be prepared for the development of the embryo-plant in its interior. At the apex of the nucleus an absorption or obliteration of cells takes place, by which a hollow cavity is formed, which becomes lined with a thin cellular membrane (epithelium), and forms the sac in which the rudiments of the embryo first appear (Fig. 752, *s*). This *embryo-sac* is surrounded by a cellular layer derived from the nucleus (Fig. 752, *n*), to which the name of *tercine* has been given. In some instances the nuclear cells or tercine appear to be the only coverings of the sac, as in the Mistleto (Fig. 753). In most cases, however, other cellular layers are formed, which first appear in the shape of annular appendages at the base, and then gradually spread over the central mass. These ovular coverings are usually two, one next the nucleus, and first formed (Fig. 754, *s*), called the *secundine*, and the other on the outside (Fig. 755, *p*), called the *primine*. These two coats or coverings of the ovule are sometimes incorporated so as to appear one (Fig. 756).

342. At the base of the ovule, these coverings and the nucleus are intimately united at one point by a cellular and vascular process, called the *chalaza* (Fig. 757, *ch*), where the nourishing vessels enter from the placenta. At the apex of the ovule they leave an opening called the *foramen* or *micropyle*, through which the influence of the pollen is afterwards conveyed. This foramen extends through both ovular coats, the opening in the outer (Fig. 755, *ex*) being the *exostome* (outer mouth), and that in the inner (Fig. 755, *end*) being the *endostome* (inner mouth). The foramen indicates the organic apex of the ovule, while the part connected with the placenta by means of the stalk (Fig. 755, *f*) called the *funiculus* or *podosperm*, is the base or *hilum*.

343. The relation which the hilum, the micropyle, and the chalaza bear to each other varies in different ovules. In an *orthotropous* or straight ovule (straight as regards its axis), the chalaza is at the hilum, and the micropyle at the opposite extremity (Fig. 752). In such an ovule the chalaza, *ch*, is at the base, and the micropyle, *m*, at the apex, and no curvature or inversion takes place either in the nucleus or in its coverings. In a *campylotropous* or curved ovule, the chalaza is still at the hilum, but the whole ovule is bent upon itself, so that the micropyle or apex approaches the hilum. This is shewn in Figure 758, which exhibits a vertical section of the ovule of Wallflower; the nucleus, *n*, is curved on itself, and so is the primine, *p*,

and secundine, *s*; the chalaza, *ch*, is at the base of the ovule, and the foramen or apex is close to it. In an *anatropous* or inverted ovule (Fig. 759), an inversion of the nucleus, *n*, takes place, so that its base, *ch*, is removed to the opposite side from the hilum, *h*, or base of the ovule, and the micropyle, *f*, is so placed as to be close to the hilum. In this case the chalaza, *ch*, is at the apparent apex of the ovule, and its connection with the placenta is kept up by a cord, *r*, called the *raphe*, consisting of cellular tissue and of spiral vessels.

344. Some represent the anatropous ovule as simply an inverted orthotropous one, with an elongated funiculus, in the form of the raphe, adherent along the side. It is probable, however, that the raphe is also in part formed by cells derived from the primine and secundine. This view is confirmed by the fact that the hilum in an anatropous ovule is not seen at the part where the raphe ends (Fig. 759, *s*), but at the part where it joins the placenta (Fig. 759, *h*). This

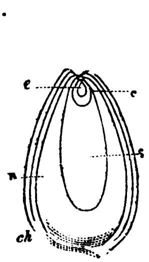

Fig. 757.

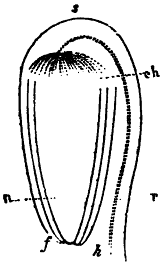

Fig. 759.

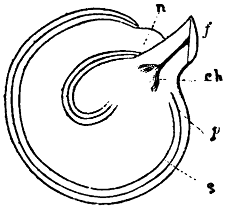

Fig. 758.

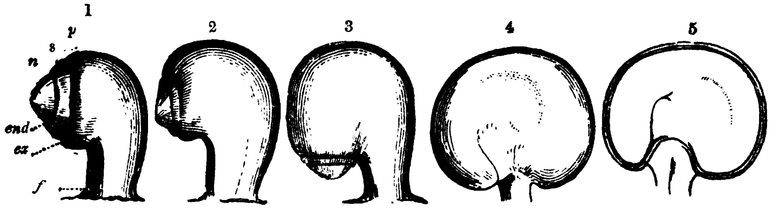

Fig. 760.

Fig. 757. Orthotropous or Orthotropal ovule of Polygonum, showing the coats of the ovule on the outside, the nucleus, *n*, the embryo-sac, *s*, containing a vesicle, *c*, in which the rudimentary embryo, *e*, is seen close to the foramen or micropyle. The chalaza is marked *ch*.

Fig. 758. Campylotropous or Campylotropal ovule of Wallflower (*Cheiranthus*), showing, *f*, the funiculus which attaches the ovule to the placenta, *p*, the primine, *s*, the secundine, *n*, the nucleus, *ch*, the chalaza. The ovule is curved upon itself, so that the foramen is near the funiculus.

Fig. 759. Anatropous or Anatropal ovule of Dandelion (*Leontodon Taraxacum*), showing the coats of the ovule surrounding the nucleus, *n*, which is inverted, so that its base, *ch*, where the chalaza exists, is removed from the base or hilum of the ovule, *h*, while the foramen, *f*, is near the base. The connection between the base of the ovule and the base of the nucleus at *s* is kept up by means of the raphe, *r*.

Fig. 760. Various stages of the development of the Campylotropous ovule of Mallow (*Malva*). The funiculus, *f*, the primine, *p*, the secundine, *s*, the nucleus, *n*, the exostome, *ex*, the endostome, *end*. In 1 the ovule is becoming slightly curved, in 2 more so, in 3 the curvature is decided, so that the foramen is near the hilum, in 4 and 5 the curvature and union of the parts is complete.

is, consequently, the true base of the ovule. When the hilum is placed midway between the micropyle and the chalaza, the ovule becomes *heterotropal*, and in such cases it frequently happens that the funiculus proceeds at right angles from the ovule, so that the latter becomes horizontal. Such ovules are considered by some as produced by a partial adhesion of the funiculus to the upper part of one side of the ovule.

345. Anatropous ovules are very common in plants. They appear to be formed with the view of allowing the pollen tubes to reach the foramen easily, as will be explained under Embryogeny. Campylotropous ovules are by no means uncommon. They are met with in Cruciferous and Caryophyllaceous plants, in Mignonette, and in the Bean. The orthotropous form is rare as a permanent condition of the ovule; it is met with in a few natural orders, such as the Buckwheat and Rock-rose tribes.

346. Many look upon the orthotropous form as being the earliest state of all ovules, and refer the other forms to changes produced during growth. The campylotropous ovule of the Mallow is traced in Figure 760 through its various phases, from its slight curvation, 1 and 2, through its more complete curvation, 3, until, by adhesion and other alterations, it assumes the forms shown in 4 and 5. So also the anatropous ovule of the Celandine is seen in an orthotropous state in Figures 751 and 754; the nucleus then begins to turn round, as seen in Figure 762, 1, and ultimately it assumes the forms exhibited in Figure 762, 2 and 3, the latter being its perfect state.

347. Ovules vary in number. Sometimes there is a *solitary* ovule in each ovary (Fig. 727, p. 251) or in each loculament, at other times there are several (Fig. 763). When the number is not great, and is uniform, the ovules are said to be *definite*, when very numerous they are *indefinite*. They are attached in various ways to the placenta, and their position in the ovary varies. When the placenta at the base of the ovary is the only part ovuliferous, then the ovule is *erect*, as in Polygonum (Fig. 761). When the ovuliferous part is above the base, and the ovules proceed obliquely upwards, they are *ascending*, as in the Pellitory, and if they are developed equally on either side of the attachment, they are *horizontal* or *peltate*, as in Crassula. When the ovuliferous part of the placenta is at the apex of the ovary, the ovules are *pendulous*, as in Valerian (Fig. 764), in the Ash (Fig. 765), and in the Mare's-tail; when below the apex, they are *suspended*, as in the Apricot (Fig. 683, p. 241), in the Red Valerian (Fig. 727, p. 251), and in the Mezereon. In the Common

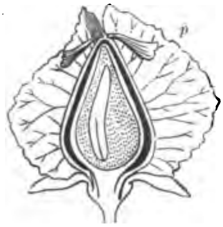

Fig. 761.

Fig. 761. Erect ovule of a species of Dock (*Rumex*). The ovary is attached to the enlarged pericarp, *p*, the placenta is at the base of the ovary, and hence the solitary ovule is erect. The ovule contains the embryo plant, which is inverted.

Thrift (Fig. 728, p. 251), and in Sumach, a funiculus extends from the placenta to the apex of the ovary, and curves downwards, *cor*, so as to suspend the ovule. When an ovary is multi-ovular (contains many ovules), the ovules may be all attached in the same way, and be placed either collaterally (Fig. 718, p. 249), or one above the other (Fig. 763); or they may be attached in different ways, so that some are erect and others pendulous. These terms apply only to the position of the ovule as respects the ovary, and they have reference alike to orthotro-

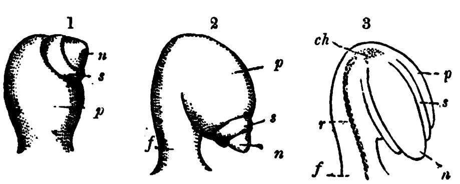

Fig. 762.

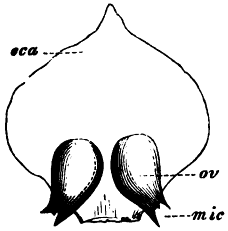

Fig. 766.

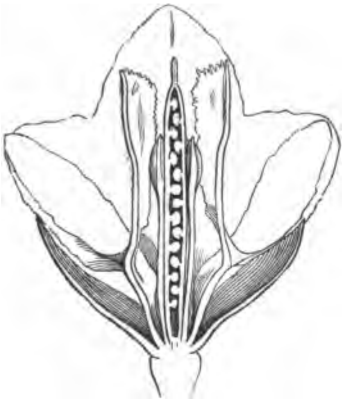

Fig. 763.

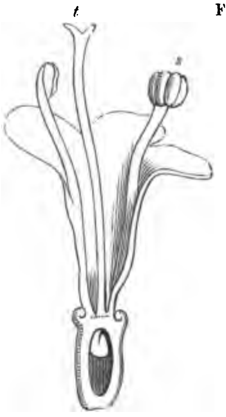

Fig. 764.

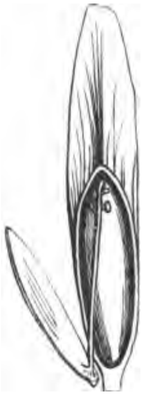

Fig. 765.

Fig. 762. Stages in the development of the anatropous ovule of Celandine (*Chelidonium*). The first two stages are seen in Figures 751 and 754, at page 256, the remaining stages are represented in the present Figure, from 1 to 3. The primine, *p*, secundine, *s*, nucleus, *n*, funiculus or umbilical cord, *f*, the chalaza, *ch*, the raphe, *r*. At 1 the ovule is seen with the nucleus slightly turned, at 2 it is much more inverted, and at 3 the subversion is complete. The connection between the base of the nucleus, *ch*, and the base of the ovule, *f*, is kept up by the raphe, *r*.

Fig. 763. Vertical section of the flower of Hypecoum. The ovary contains numerous ovules, placed one above the other, and attached alternately to either side.

Fig. 764. Flower of Valerian (*Valeriana*), cut vertically, showing the solitary pendulous ovule in the ovary. The placenta is at the apex of the ovary. The stamen, *s*, the style, *t*.

Fig. 765. Samaroid or winged ovary of Ash (*Fraxinus*), with a solitary anatropous ovule pendulous from its apex. Part of the ovary is removed, to show the cord extending to the apex, where the ovule is attached.

Fig. 766. Pistillate flower of a Fir (*Pinus*), consisting of a scale, *eca*, which is a hardened bract, and two ovules, *ov*, attached to its base. The apex of the ovules is indicated by the foramen, *mic*. Some look upon the scale as an expanded carpellary leaf. The ovules are called naked, because they are not contained in a true ovary, with a stigma attached to it.

pous, campylotropous, and anatropous ovules. Thus, an anatropous ovule may be either erect or pendulous as regards its position in the ovary. The same terms apply to the seed in its relation to the seed-vessel.

348. The position of the raphe in anatropous ovules has been examined by Mr. Clarke, who gives the following arrangement:—

1. Pendulous ovules, with the raphe next the placenta, which is the ordinary position of anatropal ovules.
2. Pendulous ovules, with the raphe turned away from the placenta, as seen in many Endogens, also in Crowfoots and Peppers.
3. Pendulous ovules, with the raphe lateral, as seen in the Malpighia and Goosefoot orders, and in several genera.
4. Erect ovules, with the raphe next the placenta, which is the ordinary occurrence in erect anatropal ovules.
5. Erect ovules, with the raphe turned away from the placenta, as seen in Composite plants, in Penæa and Calytrix.
6. Erect ovules, with the raphe lateral, which are very general in Exogens.

349. Some ovules are not contained in a true pistil, *i. e.*, in a carpel consisting of true ovary and stigma. These ovules are met with in the Cycas and Cone-bearing orders. In the former (Fig. 37, p. 21, and Fig. 89, p. 38), the ovules are arranged on the edges of metamorphosed leaves, and the pollen from the male flowers is applied directly to them, without the intervention of a stigma.* In the latter, the ovules (Fig. 766, *ov*) are covered by scales, *eca*, which are hardened bracts or floral leaves covering the female flowers. In this case also the pollen is applied to the micropyle, *mic*, of the ovules, without the intervention of a stigma.

350. Recapitulation of the general facts stated relative to the pistil before it becomes the fruit:—

1. The pistil is the central part of the flower, and consists of one or more folded metamorphosed leaves, called Carpels, which constitute the Gynœcium or female organ.
2. These carpels are developed in the same way as leaves, and they agree with the latter in structure and arrangement.
3. In monœcious, diœcious, and polygamous plants, some flowers produce a pistil without stamens, and they are called Pistilliferous, Pistillate, or female.
4. The pistil is normally in the centre of the flower, and free or superior, all the other whorls being placed around it and below it, so as to be hypogynous.
5. The pistil is often, however, united to the other whorls, more especially to the calyx; it then becomes adherent or inferior, while the other whorls are more or less epigynous.
6. A Carpel is a leaf folded upwards towards the axis, and consists of an ovary containing ovules, and of a stigma which is either sessile or supported on a style. The terms ovary, style, and stigma, are applied either to the parts of a single carpel, or to the completely united parts of a compound (syncarpous) pistil.
7. The stigma and style always mark the organic apex of the ovary, even although they may be placed in a lateral or basal position as regards the apparent summit.
8. The dorsal suture of a carpel corresponds to the midrib of the leaf, the ventral suture bearing the placenta and ovules to the united margins of the folded leaf.

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* A beautiful specimen of Cycas revoluta, with its metamorphosed fruit-bearing leaves, and ovules, has been presented to the Museum of the Edinburgh Botanic Garden by Dr. Gilbert M'Nab.

9. Placentation is of two kinds, marginal, *i. e.*, a development of cellular tissue along the ventral suture, or axile, *i. e.*, a prolongation from the axis.
10. Placentas are either central or parietal; and, when axile in their formation, they are often free in the centre, surrounded by carpellary leaves.
11. The individual carpels of which a pistil is originally formed, either continue separate, so as to form an Apocarpous pistil, or they are united, more or less, so as to form a Syncarpous pistil.
12. In an Apocarpous pistil the number of carpels forming it is evident; in a Syncarpous pistil their number is determined by counting the stigmas or styles when these are separate, or the number of loculaments and septa in the united ovaries.
13. Septa are formed by the united margins or laminæ of carpellary leaves, and are therefore vertical; each septum being double.
14. The pistil is more liable to change in the progress of growth than any of the other whorls. Its transformations depend chiefly on abortion or suppression of parts, degeneration, adhesion, rupture or absorption of septa, folding inwards of the ventral or dorsal sutures, and development of the placenta so as to form spurious partitions.
15. Ovules may be considered as cellular buds on the margins of carpellary leaves, or on the floral axis. In the one view they are marginal, in the other axile. They are attached to the placenta usually by means of a funiculus.
16. Ovules are composed of a nucleus and two evident coverings called primine and secundine, perforated at a point, called the Foramen or Micropyle, which is the true organic apex of the ovule.
17. Ovules are nourished by vessels from the placenta entering at the Hilum or base of the ovule, and proceeding to the base of the nucleus either directly or in the form of a Raphe. The base of the nucleus where the vessels enter being the Chalaza.
18. Ovules are either straight or curved, and are divided into Orthotropal, Campylotropal, and Anatropal, the last being the most common permanent form.
19. In practical Botany it is of importance to attend to the position of the hilum, foramen, chalaza, and raphe of the ovules; as well as to the position of the ovules in the ovary, whether erect or pendulous.
20. Ovules are usually contained in an ovary, and plants having such ovules are Angiospermous. Sometimes ovules are not in a true ovary, and are called naked, as in Gymnospermous plants.

b. PISTIL AFTER BECOMING THE FRUIT.

351. *The Fruit* is, properly speaking, the pistil arrived at maturity, containing the ripe seeds, in which the embryo plant is developed (Fig. 767). The simplest form of fruit is that formed by a single carpel, enclosing one or more seeds (Figs. 768 and 769). It often happens that changes take place by which some parts of the carpel are rendered succulent, and then, in place of a dry fruit, there is produced a fleshy one. This is well seen in the case of the Peach (Fig. 770), in which the outer epidermal covering of the carpel forms what is called the *skin*, the parenchymatous cells of the mesophyllum constitute the *flesh*, and the inner epidermis of the carpellary leaf is changed into the *stone;* the kernel being the ripe seed containing the embryo plant. In the Coco-nut, in place of fleshy cells, woody fibrous ones are produced; the outer layer of the husk representing the external epidermis of the ovarian carpel, the fibrous portion being the parenchyma of the carpel, and the hard shell being the inner epidermis of the carpel enclosing the seed and the embryo.

352. As in the case of the pistil, so in the fruit, the carpels composing it may be distinct or united. When the fruit consists of a single ripe carpel, or of several separate and distinct carpels, it is said to be *apocarpous* or *dialycarpous*, as in the Pea (Fig. 769), and the Carob-tree (Fig. 771, *b*), where there is a single carpel, and in the Ranunculus (Fig. 694, p. 245), and Columbine (Fig. 772), in which there are several separate mature carpels. When the mature carpels are combined, as in the Poppy (Fig. 417, p. 175), and in the Epilobium (Fig. 773), the fruit is *syncarpous*. Sometimes the mature pistils of several flowers are incorporated into one hard or succulent mass, as in the Cone (Fig. 353, p. 150), in the Mulberry (Fig. 774), and in the Fig (Fig. 366, p. 154, and Fig. 775), and in these instances, what is commonly called the fruit, consists, in reality, of a great number of fruits united together. Such fruits are called *collective* or *multiple*.

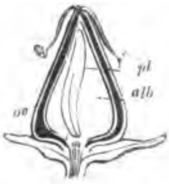


Fig. 767.

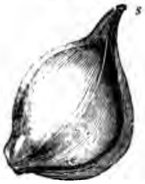


Fig. 768.

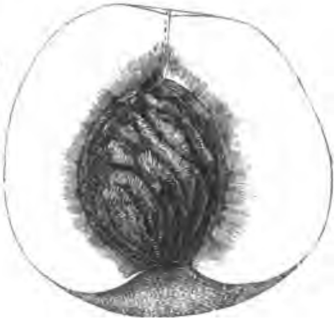


Fig. 770.

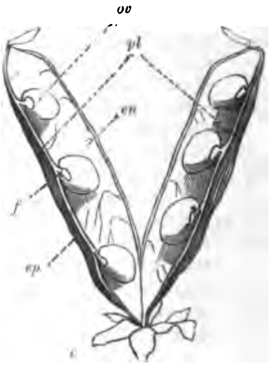


Fig. 769.

353. The fruit may be formed not merely by the pistil, but also by other parts of the flower united to it, more or less completely.

Fig. 767. Fruit of a species of Dock (*Rumex*), cut vertically. It is a monospermous indehiscent dry fruit, called an Achene, or Achænium. The outer part, *ov*, is the pericarp or seed-vessel containing the seed, with its coverings. The seed contains nourishing matter, called albumen or perisperm, *alb*, and the embryo plant, *pl*, with its cotyledons pointing downwards, and its radicle upwards. The seed is orthotropal, and the embryo is inverted. At the upper part of the pericarp two of the styles and stigmas are seen curving downwards. At the base, part of the perianth is represented.

Fig. 768. Achænium of Crowfoot (*Ranunculus*). A single-seeded seed-vessel, with the pericarp applied closely to the seed. Such fruits resemble seeds in appearance; the style and stigma, *s*, aid in distinguishing them.

Fig. 769. Legume of the Pea (*Pisum sativum*), consisting of a single carpel arrived at maturity, and containing numerous seeds (polyspermous). The pericarp consists of epicarp, or exocarp, *ep*, and endocarp, *en*. The seeds, *ov*, are attached to the placenta, *pl*, by means of the cord or funiculus, *f*. The Legume opens by the ventral and dorsal suture. The placenta, *pl*, is double, and runs along each edge of the ventral suture. At the apex of the pod the remains of the style and stigma are seen, and at the base the calyx.

Fig. 770. Fruit of the Peach (*Amygdalus persica*), consisting of the outer skin or epicarp, the flesh or mesocarp, and the stone or endocarp, enclosing the kernel or seed.

Thus, in the Apple, Pear, Medlar (Fig. 776), Gooseberry, Currant (Fig. 777), and Melon (Fig. 490, p. 197), the calyx is combined with the pistil; in the Hazel-nut (Fig. 351, p. 149), the Acorn (Fig. 350, p. 149, and Fig. 778), and Chestnut, bracts form the husk, the cup, and the burr; in the Rose (Fig. 503, p. 199), the receptacle is enlarged, and covers the pistil. Occasionally the fruit seems to consist not merely of a number of rows of transformed leaves, but of a transformed branch in addition. A good illustration of this occurs in the Chinese tree, called Hovenia, whose fruit consists of a swollen fleshy fruit-stalk, which is succulent enough to be eatable, and of a hard dry un-

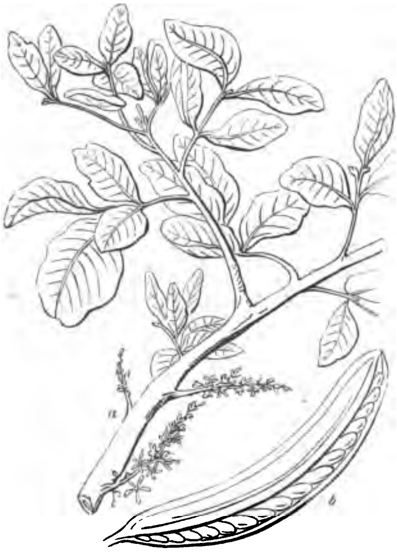
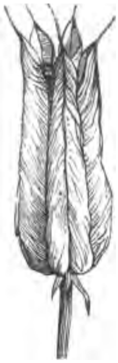


Fig. 771.



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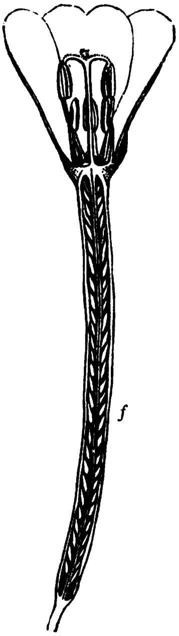


Fig. 773.

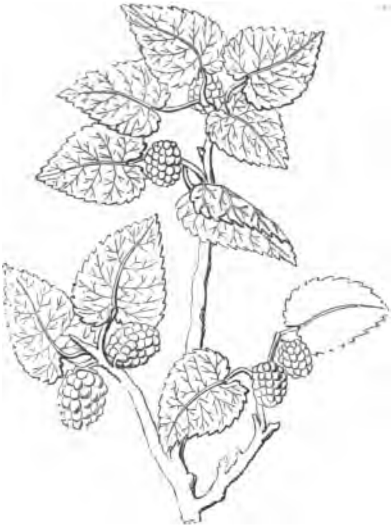
Fig. 771. Flowering branch, *a*, and fruit, *b*, of the Carob-tree (*Ceratonia Siliqua*). The leaves are pinnate. The fruit is a Legume, dehiscing by the ventral and dorsal suture, and containing numerous seeds. The fruit is formed by a single mature carpel. The tree is called in Greek *Keratia* or *Keratonia*. In Luke xv. 16, the word *Keratim* occurs, which has been translated husks. These husks appear to have been the fruit of this tree. Some have thought, apparently erroneously, that the pods of this tree supplied food to John the Baptist, and hence the tree has been called St. John's Bread, and Locust-tree. The dried pods are at the present day used as food for horses and cattle.

Fig. 772. Apocarpous fruit of Columbine (*Aquilegia vulgaris*), consisting of five separate mature carpels, with styles and stigmas.

Fig. 773. Syncarpous fruit, *f*, of Willow-herb (*Epilobium*), consisting of four carpels united together, forming a quadrilocular fruit, with numerous comose (hairy) seeds. The seed-vessel is adherent to the tube of the calyx, and the limb of the latter is superior, while the fruit is inferior. The stamens and petals are attached to the calyx (Calycifloræ). The style and stigma are seen in the centre of the flower.

eatable capsule, formed in the usual way from modified leaves. In the Pear-tree peculiar transformations sometimes take place, by which the end of a branch has a tendency to become fruit.* Some suppose the hep of the Rose to be the hollow end of the axis or branch, with leaves above it.

354. By ascertaining the anatomy and structure of the pistil, we are led to a knowledge of the nature of the fruit, and we are enabled to see the changes which take place during growth. These changes depend on increase of the parenchyma, adhesion of one part to another, obliteration of loculaments or of ovules, and the development of additional processes or partitions from the placenta, and from other parts of the pistil. Thus, the Coco-nut in its young state, is formed by three carpels, each containing a single ovule, while in its mature condition there is only one loculament and one seed. In this case the partitions between the carpels are obliterated, and one ovule is developed at the expense of the other two. These changes may be



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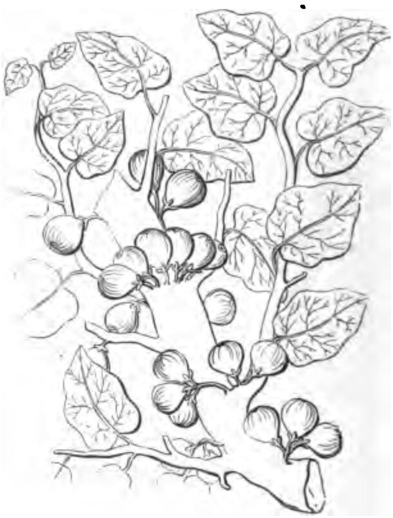

Fig. 775.

Fig. 774. Fruiting branch of the Black Mulberry (*Morus nigra*). The fruit is anthocarpous, or collective, consisting of the ovaries and envelopes of numerous flowers, united into one succulent mass. It is quite different in structure from the Raspberry. The leaves are reticulated, cordate, and serrate. The tree seems to be the *Sykaminos* of the Greeks, translated Sycamine-tree in Luke xvii. 6.

Fig. 775. Fruiting branch of the Sycamore-Fig (*Ficus Sycomorus*). The fruit is anthocarpous, or collective, consisting of a fleshy hollow receptacle, on which numerous flowers are arranged. These flowers are seen on cutting open the fruit vertically. What are called seeds in the Fig are in reality single-seeded fruits. The plant is the *Shikmoth* or *Shikmim* of the Bible, translated Sycamore (1 Kings x. 27; 1 Chron. xxvii. 28; 2 Chron. i. 15; Ps. lxxviii. 47; Is. ix. 10; Amos vii. 14; and Luke xix. 4).

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* See Gardener's Chronicle, February 15, 1851.

traced on careful examination; and even in the ripe fruit indications of them are seen in the markings on the shell. In the Hazel-nut and in the Acorn (Fig. 779), the young pistil is formed of three carpels, with two ovules in each, as seen in the Figure, but in the progress of development changes are induced by which the fruit becomes one-celled and one-seeded. In these cases a trilocular sex-ovular pistil becomes a unilocular and monospermic fruit. In the Ash (Fig. 765, p. 261), the Elm, the Beech, and the Horse-chestnut, similar changes are produced in the pistil by the abortion of ovules, and the obliteration of divisions. In the Thorn-apple the pistil is formed of two carpels, separated by a septum (Fig. 711, p. 248), while the fruit exhibits four loculaments (Fig. 712, p. 248), produced by prolongations from the placentas, forming a spurious septum in each carpel. Changes of a similar kind occur in the fruit of Petræa, and in some pods, such as the Cassia Fistula (Fig. 705, p. 247) and Astragalus (Fig. 710, p. 248).

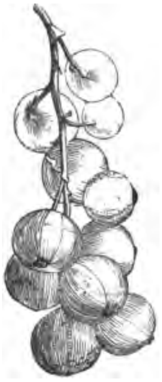
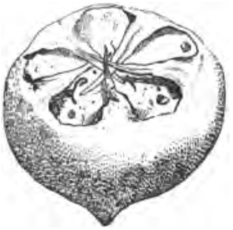


Fig. 777.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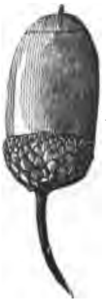
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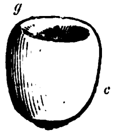


Fig. 780.

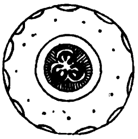


Fig. 779.

355. It sometimes happens that the receptacle or peduncle becomes succulent, and is called the fruit in ordinary language. Thus, in the Strawberry (Fig. 781), the true fruit consists of small single-seeded

Fig. 776. Fruit of the Medlar (*Mespilus germanica*), consisting of five carpels, united together by means of a fleshy mass, and adherent to the calyx, which forms part of the fruit. The withered limb of the calyx is seen at the upper part of the syncarpous fruit or pome. The seeds are contained in stony coverings, called nucules, and hence the fruit has sometimes been called a nuculanium.

Fig. 777. Raceme or cluster of red Currants (*Ribes rubrum*). Each fruit is a berry (bacca), with the calyx adherent to it. The remains of the limb of the calyx are seen at the top of the berry. The seeds are immersed in a pulpy mass, and are attached at first to parietal placentas.

Fig. 778. Acorn, or fruit of the Oak (*Quercus*), consisting of the ovary containing a single seed, and surrounded by a series of bracts which form the cup or cupula.

Fig. 779. Transverse section of the Acorn (glans), showing the three carpels with two ovules in each, of which it is originally composed. Two of the carpels and five of the ovules are obliterated during the progress of growth, so that the mature fruit is unilocular and monospermal. Surrounding the ovary the mass of bracts are seen.

Fig. 780. Fruit of the Yew (*Taxus baccata*) consisting of a single seed, *g*, surrounded by a cup, *c*, which is formed by succulent bracts united.

(monospermic), dry seed-vessels (commonly called seeds), scattered over a succulent convex receptacle; in the Rose, the true fruit consists of similar seed-vessels arranged on a fleshy concave receptacle (Fig. 504, p. 199); and in the Fig (Fig. 782), the true fruit consists of monospermic seed-vessels produced by separate flowers, and scattered over the inner surface of a concave succulent receptacle (Fig. 366, p. 154). In the Cashew, the nut or true fruit, is borne on a coloured succulent stalk, which enlarges during ripening.

356. In the interior of some fruits a pulpy substance is produced, apparently as a secretion from the inner lining of the ovary. This kind of pulpy matter is met with in the Gooseberry, Currant, Grape, Orange, and pod of Cassia Fistula. Occasionally the organs adjacent to the pistil become the succulent parts of the fruit. In Strawberry-Blite, the calyx surrounding the pistil, and separate from it, becomes red and juicy; in Gualtheria procumbens, the free calyx, after flowering, becomes red and succulent, surrounding the true fruit which is dry. In the Yew, the bracts enveloping the seed (Fig. 782, *c*), become succulent.

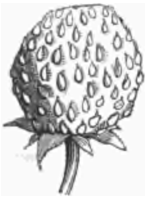


Fig. 781.

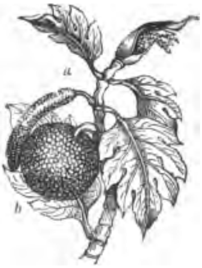


Fig. 783.

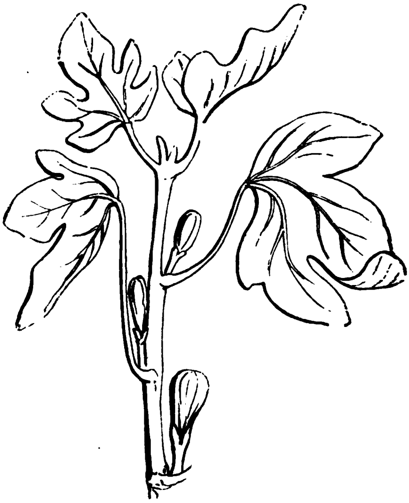


Fig. 782.

Fig. 781. The fruit of the Strawberry (*Fragaria vesca*), consisting of the enlarged succulent receptacle, or growing point, bearing on its surface numerous single-seeded carpels or achenes. Each achene has a style and stigma, and is thus at once distinguished from a seed. The calyx is seen at the base of the receptacle.

Fig. 782. Fruiting branch of the Fig-tree (*Ficus Carica*) with its palmately-lobed leaves. The fruit consists of the hollow succulent receptacle or general peduncle, enclosing numerous flowers which produce achenes. It is the *Teenah* of Scripture (Gen. iii. 7; Deut. viii. 8; 2 Kings xx. 7; Psalm cv. 33, &c.)

Fig. 783. Fruiting branch of the Bread-fruit tree (*Artocarpus incisa*), with its large pinnatifid leaves. The fruit, *b*, is anthocarpous, and consists of numerous female flowers united together so as to form a succulent mass. It is often seedless. The male flowers, *a*, are arranged in a spike.

357. The fruit, generally speaking, consists of the seed-vessel or *Pericarp*, and the *Seed*. It cannot be said to be perfect unless the seed and embryo are produced. In many cultivated fruits, however, the seeds are abortive. Thus, in the case of the Bread-fruit (Fig.

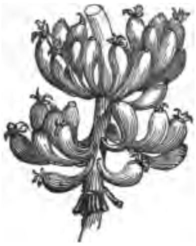
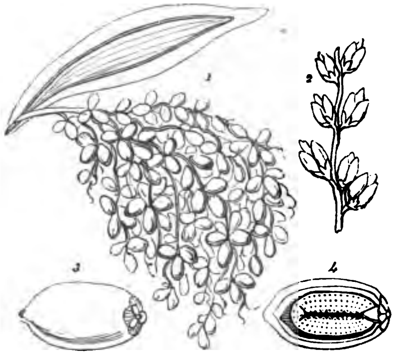


Fig. 784.



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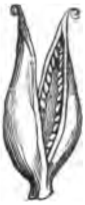


Fig. 790.

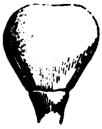


Fig. 787.

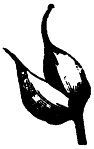


Fig. 789.

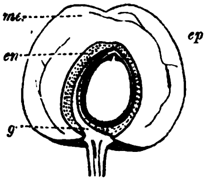


Fig. 785.

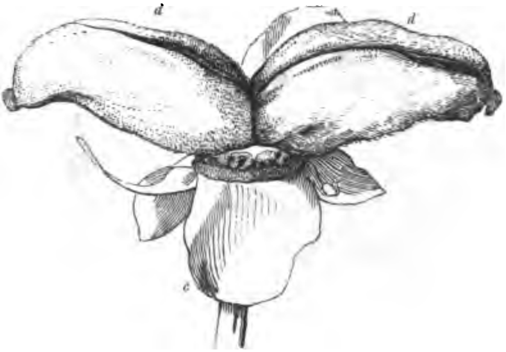


Fig. 788.

Fig. 784. Cluster of fruit of the Banana (*Musa sapientum*). The fruit is baccate, and is adherent to the perianth, the remains of which are seen at the top of each fruit. The best Bananas are usually seedless.

Fig. 785. Drupe of the Cherry (*Cerasus*), cut vertically, showing the skin, or epicarp, *ep*, the flesh, or mesocarp, *me*, and the stone, putamen, or endocarp, *en*, enclosing the seed, *g*, with the embryo.

Fig. 786. The fruit of the Date-Palm (*Phœnix dactylifera*). 1, A cluster of Dates, with the spathe which originally enclosed them. 2, A collection of flowers of the Date-Palm. 3, A Date which is a drupaceous fruit. 4, Vertical section of a Date, showing epicarp, or the outer skin, mesocarp, or the fleshy portion, and endocarp, or the thin papery-like covering of the kernel or seed. The plant is the *Tamar* of the Bible (Exod. xv. 27; Psalm xcii. 12, &c.)

Fig. 787. Fruit of Fumitory (*Fumaria*). It is a single-seeded, indehiscent fruit, called an achene.

Fig. 788. Fruit of the Pæony (*Pæonia*), consisting of two carpels, *d d*, dehiscing by their ventral suture, and denominated Follicles. Each follicle contains several seeds arranged along the ventral suture. The parts of the calyx, *c*, are below the fruit.

Fig. 789. Fruit of the Figwort (*Scrophularia*), dehiscing by two valves, in a septicidal manner.

Fig. 790. Fruit of the Gentian (*Gentiana*), dehiscing by two valves in a septicidal manner. The seeds are arranged along each margin of the placenta.

783), Banana (Fig. 784), and Pine-apple, the best fruit is seedless, and such is often true of the Orange and the Grape. The Pericarp, in its simplest state, represents the carpellary leaf, and, like it, can be separated into three parts; the outer epidermal covering called *Epicarp*, or *Exocarp* (Fig. 785, *ep*); the middle parenchymatous portion, called *Mesocarp*, *me*, and when succulent, *Sarcocarp;* and the inner epidermal covering, *en*, called *Endocarp*, and when hard and stony, *Putamen*. These three coverings are well seen in the Peach (Fig. 770, p. 264), and in the Date (Fig. 786, 4). In their original structure these parts correspond with the leaf, but changes take place during ripening, by which some cells are hardened and others become succulent, and thus the resemblance to the leaf is much obscured. That succulent fruits, such as the Peach, Apricot, and Cherry, are to be regarded as altered carpellary leaves, is shown in the case of the double Cherry, where true leaves occupy the place of the fruit (Figs. 675 and 676, p. 240). Mr. Wyville Thomson mentions instances of the common Sloe and Bird-Cherry producing red coloured follicular pods.[*]

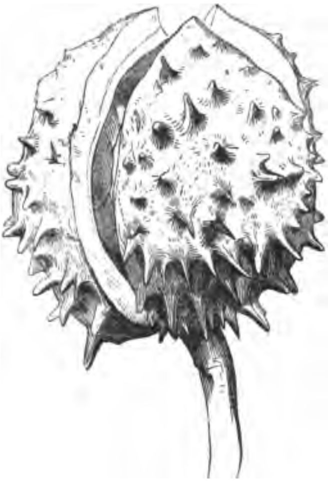
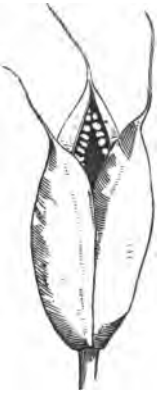


Fig. 791.



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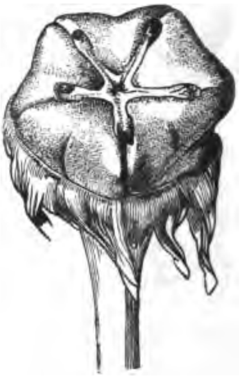

Fig. 793.

Fig. 791. Fruit of the Horse-chestnut (*Æsculus Hippocastanum*), dehiscing by three valves, which separate from each other in a loculicidal manner. The parts are normally seven, but several carpels are abortive, and only one seed comes to perfection.

Fig. 792. Fruit or capsule of the Meadow-saffron (*Colchicum autumnale*), dehiscing by three valves in a septicidal manner. The fruit is thus resolved into its three component carpels, with their styles and stigmas.

Fig. 793. Fruit or capsule of a species of Fig-Marygold (*Mesembryanthemum*), dehiscing by five valves at the apex, in a septicidal manner. When the seed-vessels of some Fig-Marygolds are moistened in water the valves separate and spread outwards. This depends on endosmose taking place, which causes curvation in an outward direction.

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[*] Specimens of these curious monstrosities have been presented by Mr. Thomson to the Museum of the Edinburgh Botanic Garden.

In many fruits, as in the Nut, the different pericarpial layers are so blended that it is not easy to mark their separation.

358. Some fruits fall without opening or dehiscing, the seeds being liberated during the process of decay; such fruits are *indehiscent* (Fig. 787). Other fruits open or dehisce in various ways, so as to scatter the seeds, and are called *dehiscent* (Fig. 788). The dehiscence takes place either in a vertical or in a transverse direction; the former is the usual mode. Vertical dehiscence takes place through the sutures, or by the separation of the parts of which a syncarpous fruit is composed. The separate parts are called *valves.* These valves are well seen in the Horse-chestnut (Fig. 791). In fruits formed by a single carpel, the dehiscence occurs either at the ventral or dorsal suture, or both. In the follicles of the Pæony (Fig. 788), the Columbine (Fig. 772, p. 265), and the Marsh Marygold, the dehiscence is ventral; in Magnolia grandiflora, the dehiscence is sometimes dorsal; while in the pod of the Pea (Fig. 769, p. 264) and of the Bean, it is both ventral and dorsal.

359. When the fruit consists of several carpels united, or is syncarpous, the dehiscence takes place either by a separation of the constituent carpels through the dissepiments, and in that case is *septicidal,* as in Figwort (Fig. 789) and Gentian (Fig. 790), where there are two valves, in Meadow-saffron (Fig. 792), where there are three valves, and in the Fig-Marygold (Fig. 793) and the Rhododendron, where there are five or more valves; or the dehiscence takes place by the dorsal suture of each carpel, and in that case is *loculicidal,* as in the Iris (Fig. 794), the Pansy (Fig. 795), the Lily, and the Horse-chestnut (Fig. 791).

360. There are modifications of these kinds of dehiscence. Thus, in the septicidal form the valves, on separating, sometimes carry the placentas with them, as in Gentian (Fig. 790), and Colchicum (Fig. 792); at other times, the placentas or placentaries are left attached to the central axis or columella, as in Rhododendron. In the case of Hura and Euphorbias (Fig. 796), each carpel, or coccus as it is called, separates from the columella, carrying with it an enclosed seed. In the loculicidal dehiscence the dissepiments may remain attached to the middle of each of the valves, and separate along with them, or the septa may adhere to the axis, and allow the valves to fall off without them, as in the Thorn-apple (Fig. 797) and Purple Convolvulus. The latter kind of loculicidal dehiscence is called *septifragal* (breaking off from the septa). In some cases the dehiscence is at first loculicidal, and afterwards the carpels separate from each other in a septicidal manner. This union of the two kinds of dehiscence is seen in some Spurges, in the Castor-oil fruit (Fig. 798), and in the Purging Flax. These various kinds of dehiscence are illustrated in diagrams 799, 800, and 801, which represent a dehiscent penta-carpellary fruit. In Figure 799, the dehiscence is septicidal; the five carpels, *l*, separate by dividing through their septa, *s*, and thus the fruit is split into its

component parts, the placentas either being attached to the edges of the valves, or remaining united in the centre to the columella. In

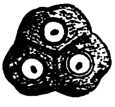


Fig. 796.

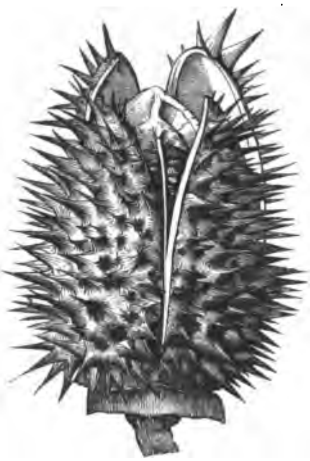


Fig. 797.

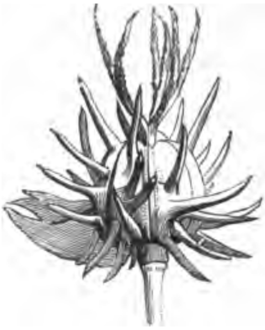


Fig. 798.

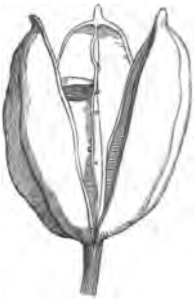


Fig. 794.

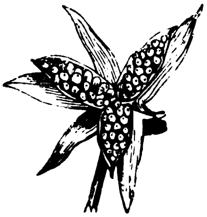


Fig. 795.

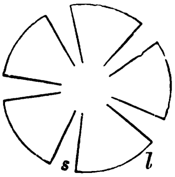


Fig. 799.

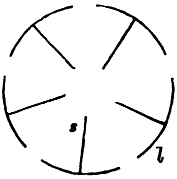


Fig. 800.

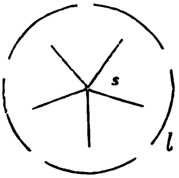


Fig. 801.

Figure 800, the dehiscence is loculicidal; the carpels, *l*, split at their

Fig. 794. The seed-vessel or capsule of the Flower de Luce (*Iris*), opening in a loculicidal manner. The three valves bear the septa in the centre, and the opening takes place through the back of the loculaments. Each valve is formed by the halves of contiguous carpels.

Fig. 795. The capsule of the Pansy (*Viola tricolor*), opening by three valves in a loculicidal manner. The placentas and seeds are placed on the middle of the valves.

Fig. 796. Transverse section of the tricoccous fruit of the Spurge (*Euphorbia*). It is formed by three single-seeded carpels called cocci, which, when ripe, separate from each other in an elastic manner, each carpel enclosing a single seed. The fruit is sometimes called a Regma.

Fig. 797. Fruit or capsule of the Thorn-Apple (*Datura Stramonium*), dehiscing by four valves, which separate in a septifragal manner, leaving the dissepiments in the centre. The valves are spiny, and hence the common name of the plant.

Fig. 798. Fruit of the Castor-oil plant (*Ricinus communis*), consisting of three carpels united together, which, when ripe, split in a loculicidal manner, and also separate from each other. Thus there is a combination of loculicidal and septicidal dehiscence. Each carpel encloses a single seed.

Fig. 799. Diagram to illustrate the septicidal dehiscence in a pentalocular capsule. The loculaments, *l*, correspond to the number of the carpels, which separate by splitting through the septa, *s*.

Fig. 800. Diagram to illustrate loculicidal dehiscence. The loculaments, *l*, split at the back, and the valves separate, bearing the septa, *s*, in their centres.

Fig. 801. Diagram to illustrate septifragal dehiscence, in which the dehiscence takes place through the back of the loculaments, *l*, and the valves separate from the septa, *s*, which are left attached to the placentas in the centre.

dorsal suture, *i. e.*, through the back of the loculaments, and the septa, *s*, remain attached to the middle of the valves, the placentas being usually attached to the ruptured septa. In Figure 801, the dehiscence is the variety of loculicidal called septifragal; the carpels, *l*, split at their dorsal sutures, but the septa, *s*, in place of being attached to the middle of the valves, are left united to the axis with the placentas.

361. In Orchis, the placentas, as represented in Figure 719, page 249, are parietal, and the seed-vessel opens by three valves (Fig. 802, *v*), which are placentiferous in their middle, but the midribs of the three carpels remain united at their base and summit, and the withered floral envelopes, *e*, are seen attached at the apex. In the pod of cruciferous plants, such as Wallflower (Fig. 803), Whitlow-grass (Fig. 804), and Shepherd's-purse (Fig. 805), as well as in the

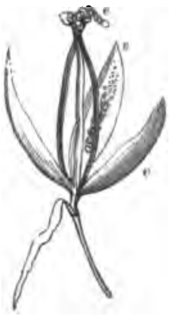


Fig. 802.

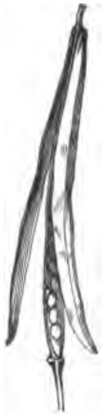


Fig. 803.

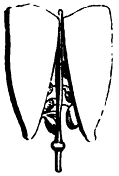
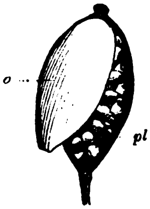


Fig. 805.



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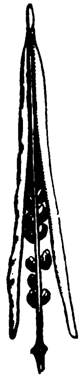

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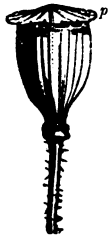

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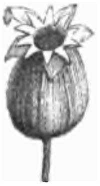


Fig. 807.

Fig. 802. Seed-vessel of an Orchid (*Orchis*), opening by three valves, *v v*, which bear the placentas and seeds in their middle. The midribs of the carpels remain united at the base and apex, and the withered floral envelopes, *e*, are seen attached at the apex.

Fig. 803. Siliqua or seed-vessel of Wallflower (*Cheiranthus Cheiri*), opening by two valves, which separate from the base upwards, leaving the seeds attached to the placentas in the middle, with a replum between.

Fig. 804. Silicula of Whitlow-grass (*Draba*), opening by two flat valves, *o*, from below upwards, leaving the parietal placentas, *pl*, in the centre, united by a membrane or replum. The seeds are attached to the placentas on either side of the seed-vessel. The partition of the seed-vessel is broad, and hence the name latiseptæ.

Fig. 805. Silicula of Shepherd's-purse (*Capsella Bursa-pastoris*), opening by two folded boat-shaped valves, which split from below upwards, leaving the narrow parietal placentas in the centre united by a frame or replum. The seeds are attached to the placentas on either side. The partition of the seed-vessel is narrow, and hence the name angustiseptæ.

Fig. 806. Seed-vessel of Celandine (*Chelidonium majus*), opening by two valves, which split from below upwards. The seeds are attached to the placentas, which are left in the centre. The seed-vessel is denominated a siliquiform or pod-like capsule.

Fig. 807. Seed-vessel or capsule of Campion (*Lychnis*), opening by ten teeth at the apex. The placenta is free central. The calyx is seen surrounding the seed-vessel, but not adherent.

Fig. 808. Capsule of Poppy (*Papaver*), opening by pores, *p*, under the broad peltate stigma.

pod-like fruit of Celandine (Figs. 806 and 809), two valves separate from the base upwards, leaving the parietal placentas united together by a cellular frame or replum, which is either entire or perforated. In vertical dehiscence the splitting sometimes takes place only at the

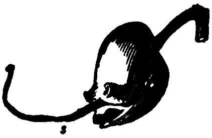


Fig. 810.

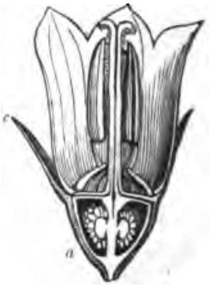
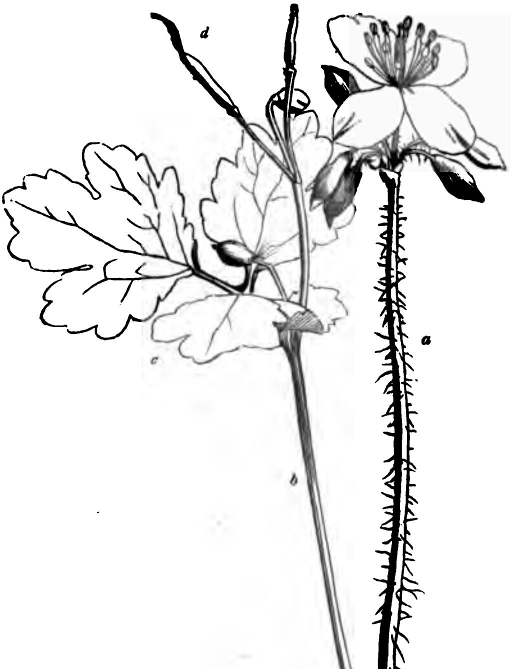


Fig. 812.



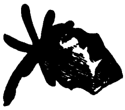


Fig. 811.

Fig. 809.

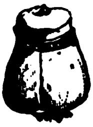


Fig. 813.

Fig. 809. Flowering stalk, *a*, of Celandine (*Chelidonium majus*). The flowers are cymose in their inflorescence. Stalk, *b*, bearing leaf, *c*, and fruit, *d*. The latter is an elongated capsule. The juice of the plant is of an orange colour.

Fig. 810. Capsule of Frogsmouth (*Antirrhinum majus*), opening by rupturing at the apex. There are usually two orifices, one corresponding to the upper carpel, and the other to the lower. The style and stigma, *s*, are seen projecting from the fruit.

Fig. 811. Seed-vessel of Mignonette (*Reseda odorata*), opening at the apex so as to leave the seeds exposed. This opening takes place in the early stage of the growth of the fruit. The orifice is large. The seeds are said to be seminude.

Fig. 812. Flower of Bell-flower (*Campanula*), with the seed-vessel, *a*, united to the calyx, *c*. The seed-vessel opens laterally by slits through the ovary and calyx.

Fig. 813. Seed-vessel of Henbane (*Hyoscyamus niger*), opening by circumscissile dehiscence. The upper part of the seed-vessel comes off in the form of a lid, and the capsule has been on this account called Pyxis or Pyxidium. The transverse line of dehiscence may be considered as corresponding to the articulations of jointed carpellary leaves like those of the orange—the lower part representing the united petioles, and the lid the united laminæ.

apex of the fruit, so that the seed-vessel opens by teeth, as in Campion (Fig. 807), and Mouse-ear Chickweed, or by pores, as in the Poppy (Fig. 808), or by rupturing, as in Frogsmouth (Fig. 810), or by one large orifice, as in Mignonette (Fig. 811). In the Bell-flower (Fig. 812), the seed-vessel dehisces in a loculicidal manner laterally, or near the base.

362. Transverse dehiscence is of rare occurrence. It is seen in Henbane (Fig. 813), Pimpernel (Fig. 814), Purslane (Fig. 815), and in various species of Monkey-pot (Fig. 816), in which the upper part of the fruit separates like a lid. This is called *circumscissile* dehiscence, and seems to indicate that the seed-vessel in these cases is formed by jointed leaves which separate at the articulations—the united petioles forming the lower part of the fruit, and the united laminæ constituting the lid.

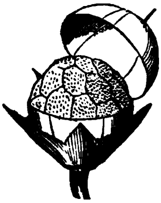
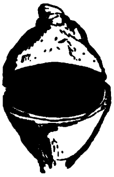


Fig. 814.



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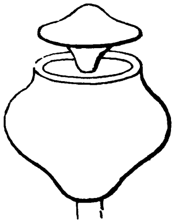

Fig. 816.

Different kinds of Fruit, and explanation of Carpological Terms.

363. A classification of fruits ought properly to be founded on a consideration of their original formation, and of their anatomical structure in the early state. This is often puzzling to the student, inasmuch as it requires that he should trace the fruit during its different stages of development. By so doing, however, he is enabled to observe the various changes which take place by absorption, obliteration, adhesion, and division of parts, and he is in a condition to explain many apparent anomalies. Thus, in the Coco-nut, he sees that there are at first three loculaments and three ovules, but as the fruit ripens, two of each of them disappear, and finally only one remains. The three ridges, however, which remain on the endocarp, are at once explained by a reference to the early condition of the nut. Such is the case with many fruits, the structure of which

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Fig. 814. Seed-vessel of the Scarlet Pimpernel (*Anagallis arvensis*), opening by transverse or circumscissile dehiscence. The capsule is called a Pyxis or Pyxidium.

Fig. 815. Seed-vessel of Purslane (*Portulaca*), opening by transverse dehiscence so as to constitute a Pyxidium or operculate capsule.

Fig. 816. Fruit (pyxidium) of the Monkey-pot (*Lecythis ollaria*), opening by a lid. The dehiscence is transverse or circumscissile, and the capsule is operculate or lidded. The seeds resemble the Brazil nuts, and are relished by monkeys, which are often entrapped when taking the nuts from the interior of the capsule.

would be obscure without a knowledge of the morphological alterations which have taken place. The names applied to fruits have a reference chiefly to their fully developed condition.

364. Without attempting to give a rigorous and minute definition of Carpological terms, which have been multiplied to a cumbrous extent, we shall merely explain some of those which are most frequently employed, arranging them according as they refer to fruits formed by a single separate flower, and which are called *Simple;* or to fruits formed by a combination of numerous flowers, and which are called *Collective*, *Multiple*, or *Anthocarpous.*

365. *Simple Fruits* may consist either of a single mature carpel, or of numerous separate carpels, arranged in one or more rows in a circular manner, on flat, convex or concave receptacles. They may be formed not only of the pistil but of the other parts of the flower united to it, and they may either be dehiscent or indehiscent, dry or succulent.

366. A *Follicle* is a fruit formed by a single mature carpel dehiscing by the ventral suture (Fig. 817). The fruit may consist of a single follicle, as is seen occasionally in the Pæony; more commonly it is formed by two (Fig. 788, p. 269) or more separate follicles arranged in a circular or spiral manner, as in the Marsh Marygold, Columbine (Fig. 772, p. 265), Larkspur, Aconite, Hellebore (Fig. 693, p. 245), Spiræa (Fig. 681, p. 241), Asclepias, and the Tulip-tree. In some anomalous follicular fruits the opening takes place by the dorsal suture.

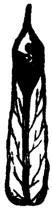


Fig. 817.

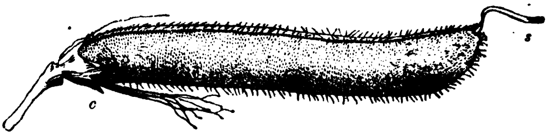


Fig. 818.

367. A *Legume.* This is commonly known by the name of *pod*, and is well seen in the case of the Pea, Bean, Lathyrus (Fig. 818), Tephrosia (Fig. 819), Acacia (Fig. 76, p. 33), Lentil (Fig. 251, p. 115), and Carob-bean (Fig. 771, p. 265). It consists of a single mature carpel dehiscing both by the ventral and by the dorsal suture (Fig. 769, p. 264), so as to separate into two halves. This kind of fruit is characteristic of the Pea order, which has hence been called

Fig. 817. Follicle of Columbine (*Aquilegia vulgaris*), consisting of a single polyspermal carpel, opening by the ventral suture.

Fig. 818. Legume or pod of a kind of Vetch (*Lathyrus*), consisting of a single polyspermal carpel dehiscing by the ventral and dorsal sutures. The seeds are attached along the ventral suture. At the base of the fruit are seen the calyx, *c*, and the remains of the stamens; and at its apex the style and stigma, *s*.

Leguminous. There are some anomalous legumes met with. In the Cassia or Cathartocarpus Fistula (Fig. 820), the legume has the markings of the sutures, but they are firmly united, and do not open so as to scatter the seeds; moreover, there are transverse partitions of a spurious nature from the inner walls dividing the pod into single-seeded cells containing a pulpy secretion in their interior. Indehiscent legumes containing one or more seeds, are met with in species of Dalbergia, Arachis, and Pterocarpus.

368. In some species of Acacia and Sainfoin (Fig. 821), in Bird's-foot, and in Sophora tomentosa, the legume is also indehiscent, and divisions between each of the seeds are formed by transverse foldings, embracing the whole thickness of the pod. This fruit is called a lomentaceous legume or a *lomentum*. It is sometimes called a moniliform pod. When mature, it separates into pieces, each of which contains a single seed. Some moniliform pods, as in Acacia arabica, are dehiscent. In some legumes, a spurious division is formed in a vertical manner by a prolongation from the placenta, or by a folding inwards of the dorsal suture (Fig. 822). In Lucerne, the legume is curiously twisted, and becomes cochleate (Fig. 823); in Scorpiurus, it is revolute and somewhat spiral; and in Colutea, it has a leafy and inflated aspect (Fig. 824), whence the plant has received the name of Bladder-Senna.* In some legumes, the outer portion or the exocarp (epicarp)

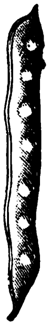


Fig. 819.

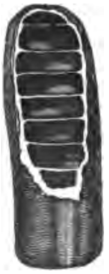
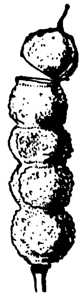


Fig. 820.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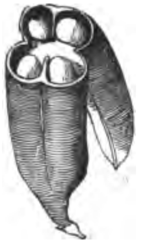
Fig. 822.

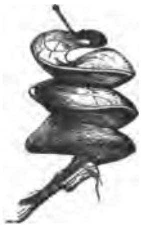
Fig. 823.

Fig. 819. Legume of a species of Tephrosia, frequently found in adulterated senna. It dehisces by the ventral and dorsal suture, and the seeds are attached to the former.

Fig. 820. Peculiar indehiscent and partitioned legume of a kind of Cassia (*Cassia* or *Cathartocarpus Fistula*). The sutures are marked along the sides of the pod; but they do not open. The seeds are in separate cavities, immersed in pulp, which is a secretion from the endocarp, or inner lining of the pod.

Fig. 821. Lomentum or lomentaceous legume of a species of Sainfoin (*Hedysarum*). Each seed is contained in a separate cavity by the folding inwards of the walls of the legume at equal intervals; and the legume, when ripe, separates transversely into single-seeded portions.

Fig. 822. Legume of Milk-vetch (*Astragalus*), which is spuriously bilocular by the folding inwards of the dorsal suture. The legume is opened transversely to show the partition.

Fig. 823. Spiral or cochleate legume of Lucerne (*Medicago*). It is coiled up in a helicoid or cochlear manner, and when the convolutions are very close and appressed, it is difficult to determine its leguminous character.

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* For a full account of the different kinds of Legumes, with figures, see Ralph's Icones Carpologicæ, Part i. Leguminosæ.

separates from the endocarp, which still remains covering the seeds. Such pods are seen in some species of Entada, and they are called spuriously dehiscent. The number of seeds in the legume varies. Some legumes are monospermal, as Gleditschia monosperma, Gourliæa, Voupa, Dipterix odorata, Geoffroya superba, Erythrina monosperma, and Copaifera officinalis. Others are dispermal or trispermal, as some species of Bauhinia, Dalbergia, Pterocarpus, and Arachis; again, in Cassia Fistula, the seeds often amount to nearly 100. In some indehiscent monospermal legumes, as Detarium, the coverings become succulent, so that they are really drupaceous, thus establishing a

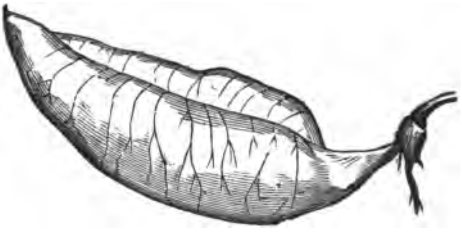
Fig. 824.

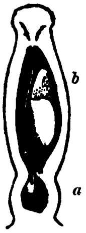

Fig. 829.

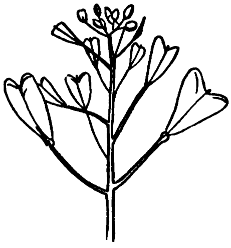
Fig. 826.

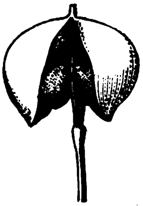
Fig. 827.

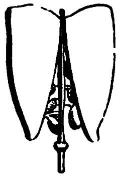
Fig. 828.

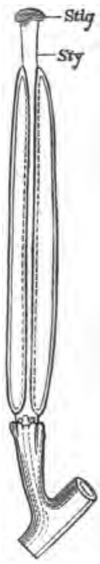

Fig. 825.

Fig. 824. Inflated or Bladdery legume of the Bladder-senna (*Colutea arborescens*). The legume retains its leafy appearance, and its walls are not applied closely to the seeds.

Fig. 825. Siliqua of Wallflower (*Cheiranthus Cheiri*), composed of two, or, as some say, four carpels united. It opens by two valves which separate from below upwards. The placentas are parietal, and are left united by a cellular frame or replum, when the valves separate. The seeds are attached along each margin of the siliqua. The style, *sty*, and the stigma, *stig*, remain attached to the fruit.

Fig. 826. Fruiting branch of the Shepherd's-purse (*Capsella Bursa-pastoris*). The fruit is a silicula, or short pod, composed of two or four carpels, opening by two valves, which separate from below upwards. The placentas are left in the middle, united by a spurious dissepiment or replum.

Fig. 827. Silicula of the Scurvy-grass (*Cochlearia officinalis*), opening by two convex valves which separate from below upwards. The spurious septum or phragma is broad (latiseptæ).

Fig. 828. Silicula or pouch of Shepherd's-purse (*Capsella*), opening by two folded valves, which separate from below upwards. The phragma is narrow (angustiseptæ).

Fig. 829. Peculiar indehiscent siliqua of the Sea-Kale (*Crambe maritima*), in which the lower part of the pod, *a*, is seedless, and appears as a stalk, while the beak or upper joint of the pod, *b*, contains one or two seeds.

connection between the Leguminous and Rosaceous plants. In other indehiscent monospermal legumes, as Amphynemium, there is a membranous wing, so that the fruit resembles some varieties of samara.

369. A *Siliqua* is another kind of pod, formed (according to most authors) by the union of two carpellary leaves with parietal placentas, and dehiscing by two valves which separate from below upwards (Fig. 803, p. 273). It is well seen in the common Wallflower (Fig. 825) and in other Cruciferous plants (Fig. 374, p. 157). The two valves separate from the placentas, leaving them united by a cellular prolongation or replum (Fig. 707, p. 248), which divides the seed-vessel vertically into two loculaments. This replum is sometimes partially absorbed (Fig. 708, p. 248), and the siliqua is then unilocular (monothecal).

370. A broad and short siliqua (Figs. 804 and 805, p. 273, and Fig. 827) has received the name of *silicula*. In it, (the silicle) the carpellary leaves are either united together, so that the septum is in the broadest diameter of the pod (latiseptæ), as in Thlaspi, Draba (Fig. 804, p. 273), and Scurvy-grass (Fig. 827); or the carpels are folded so that their dorsal suture is prominent, and the replum is narrow or linear (angustiseptæ), as in the Shepherd's-purse (Figs. 826 and 828).

371. In the Siliqua, the style (when present) and the stigma remain adherent (Fig. 825, *sty*, *stig*). A siliqua may be divided transversely like a lomentum into single-seeded loculaments, as in Raphanus maritimus. Such a siliqua is indehiscent. In the Sea-Kale (Fig. 829), there is a jointed siliqua, the upper joint (beak) of which contains one or two seeds, while the lower is abortive and appears like a fruit-stalk. In Woad, the silicle becomes by abortion one-seeded, and by the absence of the replum unilocular. Occasionally a siliqua exhibits divisions on its inner walls which are not seen externally. Some look upon the siliqua as originally formed of four carpels, two of which are abortive; in this way the tendency to tetramerous symmetry is traced in the pistil.*

372. A *Capsule* is a dry syncarpous fruit dehiscing either vertically by valves, teeth, or pores, or transversely by a lid. It is composed of several carpels united, and it may exhibit all the kinds of dehiscence to which reference has already been made (¶ 358). In Caryophyllaceous plants, the dehiscence of the capsule often takes place by short valvular teeth (Fig. 807, p. 273), in the Mahogany fruit by complete valves which separate from below upwards, in Colchicum (Fig. 792, p. 270), and in Cotton (Fig. 101, p. 44) by valves separating from above downwards, in the Poppy (Fig. 808, p. 273) by pores below the stigma, in Frogsmouth (Fig. 810, p. 274) by rupturing at the apex, in Mignonette by becoming patent at the apex (Fig. 811, p. 274), in Campanula (Fig. 812, p. 274) by irregular

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* Martins, Teratologie Vegetale, 50.

openings near the base, in Henbane (Fig. 813, p. 274) by a lid, in which case the capsule sometimes receives the name of pyxidium, in Spurges (Fig. 796, p. 272) by the sudden separation of elastic cocci or carpels, each containing one seed (Fig. 830), and in the Balsam (Fig. 831) by the separation of five elastic valves which coil upwards in the manner represented in Figure 832.

373. An *Achænium* or *achene* is a dry indehiscent one-seeded (monospermous) fruit, as in Fumitory (Fig. 833) and Crowfoot (Fig. 768, p. 264). It is formed of a single carpel which is closely applied to the seed. At first sight it is difficult to distinguish this kind of seed-vessel from a seed, and hence Linnæus termed some achene-bearing plants naked-seeded (gymnospermia). The presence of the style and stigma, as in the Nettle (Fig. 834) and in the fruit of Carex (Fig. 835), aids in the determination. It is common to find several separate achenes forming the fruit. In Buttercups, the achenes are aggregated on a convex receptacle (Fig. 694, p. 245), in the Strawberry they are placed on a convex succulent receptacle (Fig. 695, p. 245), and in the Rose on a concave receptacle (Fig. 696, p. 246). In all these cases, the presence of styles and stigmata enables the student to ascertain that what are commonly called seeds are in reality fruits. The styles are sometimes remarkably elongated and feathery, as in Traveller's-joy (Fig. 836, *s*) and in the Pasque-flower Anemone.

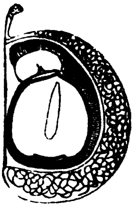
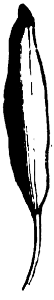


Fig. 830.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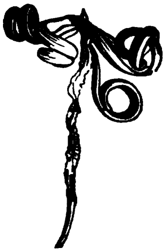
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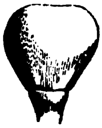
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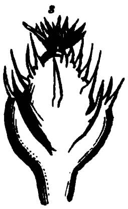


Fig. 834.

Fig. 830. A Coccus or single carpel of Spurge (*Euphorbia*), separated from the other two, and cut longitudinally. It contains a single albuminous seed, with the embryo in the centre. At the upper part of the seed a kidney-shaped body is seen, which is a kind of aril proceeding from the edges of the micropyle.

Fig. 831. The ripe fruit of the Balsam (*Impatiens noli-me-tangere*), consisting of a five-valved capsule, which opens with great force when touched. Hence the name, Touch-me-not.

Fig. 832. The capsule of the Balsam (*Impatiens*), opening by five recurved elastic valves, so as to scatter the seeds.

Fig. 833. The fruit of the Fumitory (*Fumaria*). It is indehiscent and monospermal, and has received the name of Achænium or achene.

Fig. 834. Achene of the common Nettle (*Urtica*), surrounded by the perigone, and with the penicillate stigma, *s*, at the apex. The achene has hairs on its surface.

374. In the instances already noticed, the numerous achenes are the produce of a single flower, but cases occur, such as the Fig (Fig. 366, p. 154) and Dorstenia (Fig. 367, p. 154), in which they are each the produce of a separate flower. In the Borage and Mint orders, the two or four achenes forming the ripe fruit (Figs. 837 and 838) are at first united, and even when matured, there is a common style which is attached to the apparent base of each achene. Such cases may be considered as resembling two or four-celled capsules dehiscing in a septicidal manner, each division enclosing a single seed, as in Hura and Spurges.

375. Cases also occur in which the achænia are united to the tube of the calyx. Thus in Composite plants, such as the Thistle and Dandelion (Figs. 364 and 365, p. 154), and in Groundsel (Fig. 839),

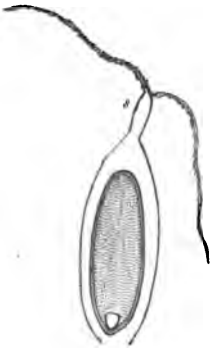


Fig. 835.

Fig. 835. Achene of a species of Sedge (*Carex*), cut vertically, showing the pericarp, with the style and stigmas, *s*, and the single albuminous seed in the interior, with the small embryo at the base of the albumen.

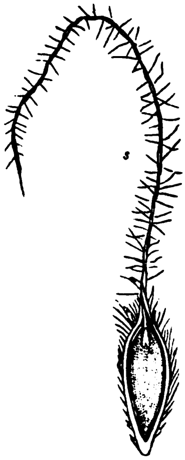


Fig. 836.

Fig. 836. Caudate Achænium of the Traveller's-joy (*Clematis*), cut vertically. It is an indehiscent one-seeded seed-vessel, with a long twisted feathery style, *s*, attached to it like a tail. The embryo is seen at the apex of the seed with the albumen surrounding it.

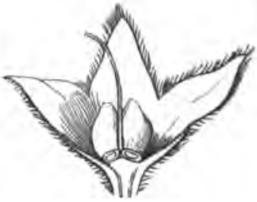


Fig. 837.

Fig. 837. Calyx and fruit of Comfrey (*Symphytum*), cut vertically. The fruit is divided by the folding of the ovary into four single-seeded portions or achænia, two of which are seen in the figure, and the style appears to arise from the base of the carpels. Linnæus erroneously called these plants naked-seeded.

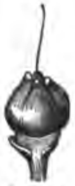


Fig. 838.

Fig. 838. Fruit of one of the Borage tribe (*Cerinthe*), divided into four achænia, with the style in the centre, proceeding from the apparent base of the carpels. Linnæus by mistake called these achænia four naked seeds.

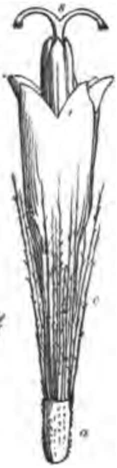


Fig. 839.

Fig. 839. Tubular flower of a species of Groundsel (*Senecio*), showing the single-seeded indehiscent seed-vessel or achænium, *a*, at the base. The tube of the calyx is adherent to it, and the limb of the calyx appears in the form of pappus, *c*, surrounding the gamopetalous corolla. The united anthers and bifid style, *s*, are seen in the centre of the flower. Some call the fruit of Composite plants such as this a Cypsela, considering it as formed originally of two monospermous carpels, one of which is abortive.

what are called seeds are in reality single-seeded fruits, each produced by a separate flower, with the tube of the calyx united to it, and the limb of the calyx appearing as a rim or as a hairy appendage, called pappus (¶ 263). The fruit in these plants seems to be originally formed of two carpels, as indicated by the divisions of the style and by the stigmata, but only one of the carpels comes to maturity.

376. In Umbel-bearing plants, such as Hemlock, Fool's-parsley (Fig. 379, p. 159), and Cummin (Fig. 347, p. 148), two achænia, invested by the tube of the calyx, are united by their faces, so as to form a compound fruit called a *cremocarp*, with a division or *commissure* between them (Figs. 840 and 841). This fruit, when ripe, shows its composition by separating into two achenes (called here, mericarps and hemicarps), which are suspended by a slender central stalk or axis, called a *carpophore* (Fig. 842). The outer surface of these mericarps is marked by ridges and furrows, and there are often peculiar vittæ or receptacles of oil (¶ 60) present in the pericarp.

377. It sometimes happens that the pericarp is not closely applied to the seed, but surrounds it like a bladder, and in that case, the achene has received the name of *utricle*. This variety of achene is seen in the Goosefoot order and in the Knawel. The achene and utricle are often surrounded closely by the calyx or perianth without being adherent, as in the Dock (Figs. 843 and 844) and in Carex.

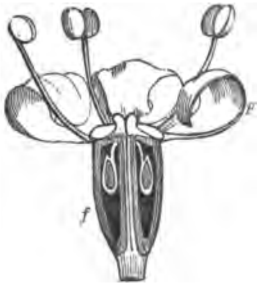


Fig. 840.

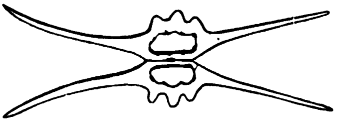


Fig. 841.

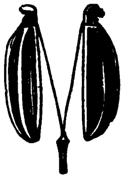


Fig. 842.

378. A *Caryopsis* is a dry indehiscent monospermous seed-vessel resembling an achænium, but differing in the complete adhesion and

Fig. 840. Flower of Fennel (*Fœniculum vulgare*), one of the Umbelliferæ cut vertically, showing the fruit, *f*, composed of two single-seeded carpels, or achenes, united, so as to form a cremocarp. The pendulous seeds are seen in the carpels or mericarps. The two styles are seen at the apex of the fruit, with their dilated bases formed by an epigynous disk. The points (apicula) of the petals, *p*, are turned inwards. The calyx tube is adherent to the fruit, and the limb of the calyx is often obsolete. The fruit is therefore inferior.

Fig. 841. Transverse section of the fruit of another umbelliferous plant (*Angelica*). It is a cremocarp, formed by two hemicarps or achenes. Prominent ridges with depressions are seen on the surface of the fruit. The lateral ridges spread into broad wings, marked by the elongated processes in the figure.

Fig. 842. The fruit of the Fennel (*Fœniculum vulgare*) arrived at maturity. It separates into two cocci or achænia, each of which is marked with obtuse prominent ridges on the surface, and is suspended from the summit of a process of the axis (columella), called a carpophore.

incorporation which exists between the pericarpial covering and the seed. It is seen in the common cultivated grains, as Wheat (Figs. 845, 846, and 847), in Oats (Fig. 848), and in general in all Grasses. In these plants, the pericarp cannot be separated from the seed. Hence the grains of Wheat, Maize, Barley, Rye, and Oats, are in common language called seeds. It is only by examining them in the early state, and noticing the styles (Fig. 845), that we can determine their real nature. In the caryopsis, it is believed that there were originally, at least, two carpels, as indicated by the styles, one of which is abortive.

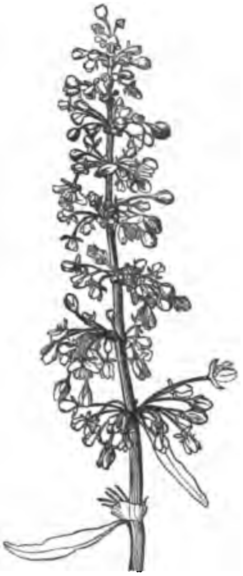
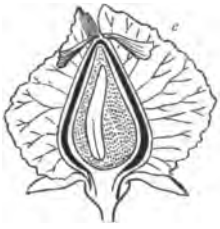


Fig. 843.



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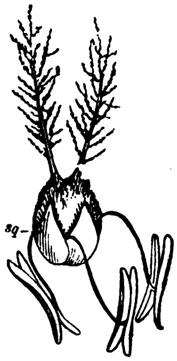


Fig. 845.

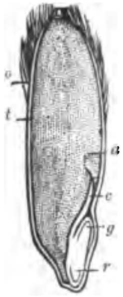


Fig. 848.

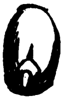


Fig. 846.

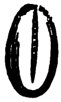


Fig. 847.

379. A *Nut* is a dry unilocular one-seeded indehiscent fruit with a hard covering. In its early state, it is usually composed of two or

Fig. 843. Flowering branch of a species of Dock (*Rumex Patientia*), in which the achene is surrounded closely by the inner divisions of the perianth. The flowers are produced in cymose clusters.

Fig. 844. The fruit of a Dock (*Rumex*), cut vertically, showing the wing-like processes outside, *c*, which are the parts of the perianth enclosing the fruit or achene, with its albuminous seed and eccentric embryo.

Fig. 845. Young fruit or caryopsis of Wheat (*Triticum*), showing the scales outside, *sq*, the three stamens, and the feathery styles at the summit.

Fig. 846. Caryopsis or grain of Wheat (*Triticum*), seen on its outer face, with the embryo lying at lower part on one side.

Fig. 847. Caryopsis or grain of Wheat (*Triticum*), seen on its inner face, with a groove on the surface.

Fig. 848. Caryopsis, or single-seeded grain of Oats (*Avena*). The fruit and seed are incorporated. The pericarp, *o*, bears the styles and stigmas, and encloses the seed, *t*, with its albumen, or perisperm, *a*, and its embryo, consisting of the cotyledon, *c*, the gemmule, *g*, and the root, *r*.

more carpels, with one or more ovules in each; but, in the progress of growth, all disappear except one. It is illustrated by the Hazel-nut (Fig. 351, p. 149), the Chestnut, the Acorn (Fig. 257, p. 116, Fig. 350, p. 149, and Fig. 778, p. 267), and the Coco-nut. In many cases it is surrounded by a series of bracts forming an involucre, seen in the husk of the Nut, the cup of the Acorn, and the burr of the Chestnut. Some restrict the term nut (glans) entirely to such cases. The pericarp of the nut has its parts frequently so united as to be indistinguishable. In the Coco-nut, however, the pericarp can be separated into an epicarp or outer covering, a fibrous mesocarp, and a stony endocarp, marked with three ridges, and three depressions, one of which is perforated. The epicarp of the nut of the Sago-Palm is scaly.

380. A *Samara* is a nut or achænium, in which the pericarp is extended in the form of a winged margin or apex. There are originally two carpels united, but one of them is frequently abortive. This samaroid fruit occurs in the Maple and Sycamore (Figs. 849 and 850), the Ash (Fig. 851), and the Elm. The samara of the Sycamore opens by splitting into two in a septicidal manner, as seen in Figure 850.

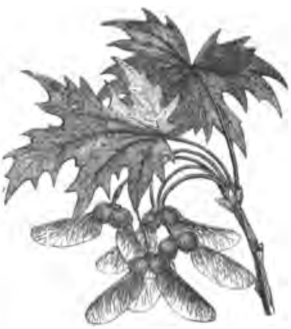


Fig. 849.

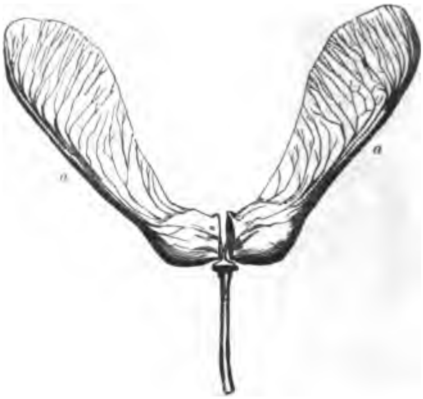


Fig. 850.

381. A *Drupe* is the general name given to what are called stone-fruits, such as the Peach (Fig. 770, p. 264, and Fig. 852), the Plum, the Cherry (Fig. 785, p. 269), the Apricot, the Date (Fig. 786, 3 and 4, p. 269), the Olive (Fig. 853), and Coffee (Fig. 854). It is a one-celled, one or two-seeded indehiscent fruit, having a fleshy mesocarp, which is hence denominated sarcocarp. In the Peach, the epicarp is the separable skin, the sarcocarp is the flesh which is eaten, and the endocarp is the hard shell or putamen, which can be split into two

Fig. 849. Branch of the Sugar-Maple (*Acer saccharinum*), bearing a cluster of samaroid fruit.

Fig. 850. Samara of the Maple (*Acer*), consisting of two achænia or nuts, with winged appendages, *a a*, at the back of the carpels. The two winged fruits separate from each other when ripe.

parts. In the Walnut (Figs. 855, 856, and 857), the putamen is divided in a marked manner into two, and from its interior bony partitions extend, so as to form lobes in the seed or kernel. Some fruits, such as the Almond (Figs. 858 and 859), are called drupes or drupa-

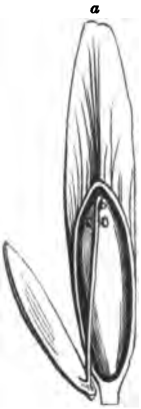


Fig. 851.

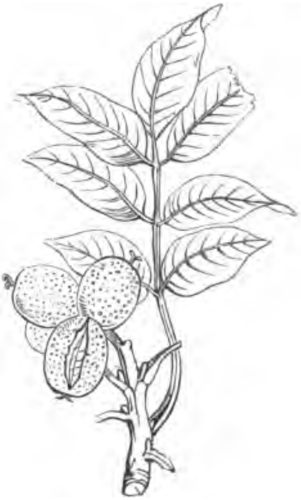


Fig. 855.

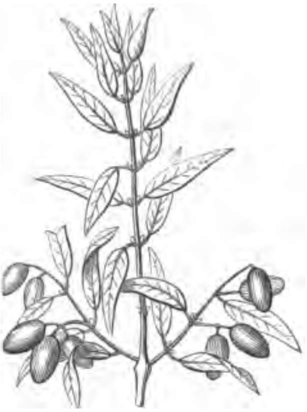
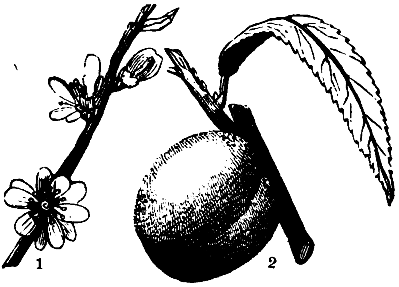


Fig. 853.



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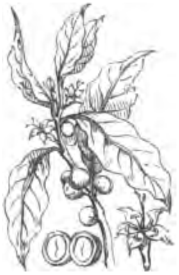


Fig. 854.

Fig. 851. Samara of the Ash (*Fraxinus excelsior*) laid open, showing the single pendulous seed. There were originally two carpels and two ovules, but one of each is abortive. The fruit has a winged appendage, *a*.

Fig. 852. Flowering and fruiting branches of the Peach (*Amygdalus persica*). The flowers, 1, have numerous stamens attached to the calyx. The fruit, 2, is a Drupe, consisting of epicarp, mesocarp or sarcocarp, and endocarp or putamen, enclosing the kernel or seed.

Fig. 853. Drupes of the Olive-tree (*Olea Europæa*). The fruit contains much oil, which is procured by expression. The plant is the *Zait* or *Sait* of the Bible (Gen. viii. 11; Deut. vi. 11; viii. 8; 1 Kings vi. 23, &c.)

Fig. 854. Branch of the Coffee-tree (*Coffea arabica*), bearing flowers and fruit. The latter are Drupes, having a succulent mesocarp. The seeds have horny albumen and a small embryo.

Fig. 855. Fruiting branch of the Walnut tree (*Juglans regia*). The fruit is a Drupe. The tree seems to be the *Egoz* of Scripture, translated *nuts* in the Song of Solomon vi. 11.

ceous, in which the sarcocarp is not succulent. Many call the Cocoanut a drupe, with a fibrous mesocarp. There seems to be, in reality,

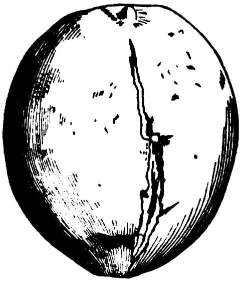


Fig. 856.

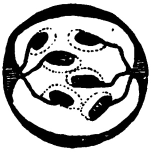


Fig. 860.

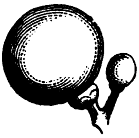


Fig. 861.

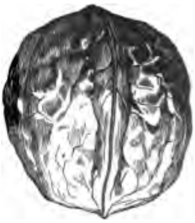


Fig. 857.

Fig. 858.

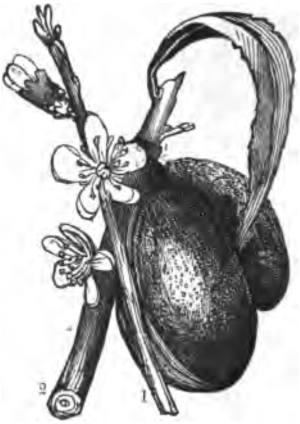


Fig. 859.

Fig. 856. The Walnut (*Juglans*), a drupaceous fruit sometimes called Tryma.

Fig. 857. The Walnut with the epicarp and mesocarp removed. The hard endocarp encloses the seed. From the inner surface of the two-valved endocarp hard processes extend inwards, which divide the kernel into numerous convoluted portions.

Fig. 858. The Almond-tree (*Amygdalus communis*), the fruit of which is a Drupe with a tough mesocarp. The Hebrew word *Shaked* is generally translated Almond (Gen. xliii. 11; Exod. xxv. 33, 34; xxxvii. 19; Numb. xvii. 8). The word *Luz*, which occurs in Genesis xxx. 37, and is there translated Hazel, appears to be the name of the Almond-tree, while *shaked* is the name of the fruit.

Fig. 859. Flowering branch, 1, and fruiting branch, 2, of the Almond (*Amygdalus communis*). The plant belongs to the drupaceous section of Rosaceæ. The stamens are numerous, attached to the calyx, and the fruit is a peculiar drupe with a tough leathery mesocarp. The endocarp is the shell of the almond, and the kernel is the seed.

Fig. 860. Fruit of the Gooseberry (*Ribes Grossularia*), cut vertically, showing the seeds attached to parietal placentas, and immersed in pulpy matter, which is formed partly from the endocarp and partly from the testa of the seed. The fruit is called a Bacca. The calyx is adherent to it.

Fig. 861. Baccate fruit of the Vine (*Vitis vinifera*), called Uva or grape. The seeds are attached to a central placenta, and are immersed in pulp which is a secretion for the inner lining of the pericarp. The calyx does not form part of the fruit.

in such cases, a transition from the drupe to the nut. The aggregation of several drupes forms the fruit of the Raspberry, the Bramble, and the Quassia plant (Fig. 316, p. 135).

382. A *Berry* or *Bacca*, is the name given to all indehiscent syncarpous fruits, the seeds of which are immersed in a pulpy or fleshy mass. Such fruits are collectively called baccate or berried. In the true berry, such as the Gooseberry and Currant (Fig. 777, p. 267), the calyx adheres to the fruit, and the placentas are parietal (Fig. 860), while in the grape (uva) the ovary alone is present (Fig. 861), and the placentas are central. Instances of baccate fruits are seen in Solanaceous plants, such as the Potato, Egg-plant, Mandrake (Fig. 862), Belladonna (Fig. 863), and Winter Cherry (Fig. 501, p. 199), as well as in the Mistleto (Fig. 864).

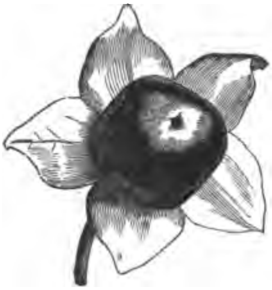


Fig. 863.

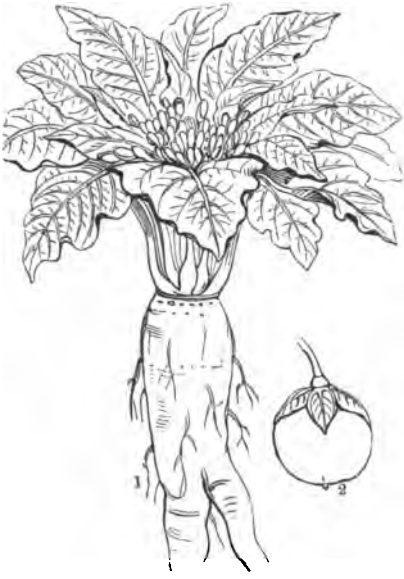


Fig. 862.

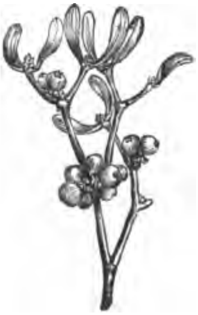


Fig. 864.

383. In the Pomegranate there is a peculiar succulent berried fruit,

Fig. 862. Plant and berried fruit of the Mandrake (*Atropa Mandragora*). The plant, 1, has a very large root, with a thick cluster of leaves concealing the flowers. The fruit, 2, is succulent, and not adherent to the calyx. The plant is doubtfully supposed to be the Hebrew *Dudaim* mentioned in Genesis xxx. 14-16; and in the Song of Solomon, vii. 13.

Fig. 863. Berried fruit of Deadly Nightshade (*Atropa Belladonna*). The calyx does not form part of the fruit. The mesocarp becomes succulent. The berry is of a beautiful shining black colour.

Fig. 864. Baccate fruit of the Mistleto (*Viscum album*). The matter surrounding the seeds is very viscid and tenacious, and has been used for bird-lime.

called a *balausta*, in which the pulpy cells are arranged in two rows, some of which are in the centre round the axis, and others are placed outside, all being adherent to the calyx. In Figure 865, there is represented a transverse section of the lower portion of the Pomegranate in the young state, showing three carpels; and in Figure 866, a similar section of the upper portion, showing five carpels. Hance says that the lower cells arise from a central row of carpels, the cohering apices of which form the septum between the two chambers of the fruit, the ovules arising from the two united margins of the same carpellary leaf, and being directed towards the circumference of the ovary; while the upper cells are formed by an outer series of longer carpels alternating with the others, the cohering summits constituting the whole, or, at all events, the external portion of the style, and the ovules are borne on the entire inner surface of the carpidia, as in the Water-Lily—the cells being also frequently divided by spurious septa arising from the midrib. The peculiar appearances are traced to the existence of two rows of carpels, and the contraction caused by the calyx. In the Orange there is a modification of the berry, called *hesperidium*, in which there is a separable rind not formed by the calyx, consisting of epicarp and mesocarp, and pulpy separable cells formed by the endocarp (Figs. 867 and 868).

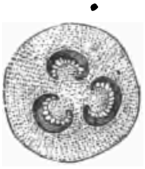


Fig. 865.

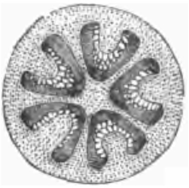


Fig. 866.

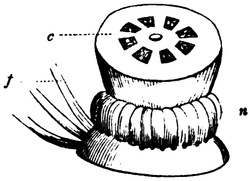


Fig. 867.

384. A *Pepo*. This is a fruit allied to the berry, occurring in the Cucumber (Fig. 869), Gourd, Melon (Fig. 327, p. 139, and Fig. 870), and Colocynth (Fig. 871). It consists of three carpels united, covered by a firm rind, which is partly formed by the calyx. The placentas are by some considered as parietal, and as sending processes inwards, by others they are looked upon as central, and as sending processes outwards, which reach the walls of the fruit and then curve backwards, bearing the seeds. The processes proceeding from the

Fig. 865. Transverse section of the lower part of the berried fruit of the Pomegranate (*Punica Granatum*), showing three carpellary divisions, with ovules situated on projecting central placentas, and looking towards the circumference of the fruit.

Fig. 866. Transverse section of the upper part of the berried fruit of the Pomegranate (*Punica Granatum*), showing five carpellary divisions, with the ovules attached to placentas projecting inwards, and looking towards the centre. The Pomegranate is a peculiar baccate fruit, with an adherent calyx, and it has received the name of Balausta. There are two rows of carpels in it, the arrangement of which becomes complicated during growth.

Fig. 867. Young fruit of the Orange (*Citrus Aurantium*) cut transversely, showing numerous central pulpy cells, with partitions, *c*, between them. The fruit is surrounded by an annular disk, *n*, below which are seen the remains of the stamens, *f*.

axis to the walls are usually obliterated, according to the latter view, giving rise to the appearance of the placentas being parietal. The fruit thus becomes one-celled. A transverse section of the Melon is given in Fig. 874, in which *pl* indicates the placentas, *cl* the septa, and *s* the processes connecting the curved placentas with the centre. In the Plantain and Banana (Figs. 873 and 875), the fruit is allied to the pepo, consisting of three carpels, with parietal placentas, the perianth being adherent to the ovary, and the seeds immersed in a pulpy mass when ripe. These plants rarely ripen seed when the fruit is of good quality. In the fruit of the Papaw-tree (Fig. 872), which resembles the pepo, the placentas are distinctly parietal, but the rind is not formed by the calyx.

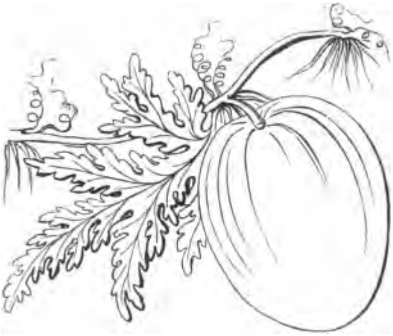


Fig. 870.

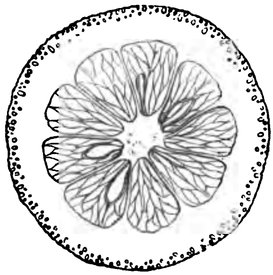


Fig. 868.

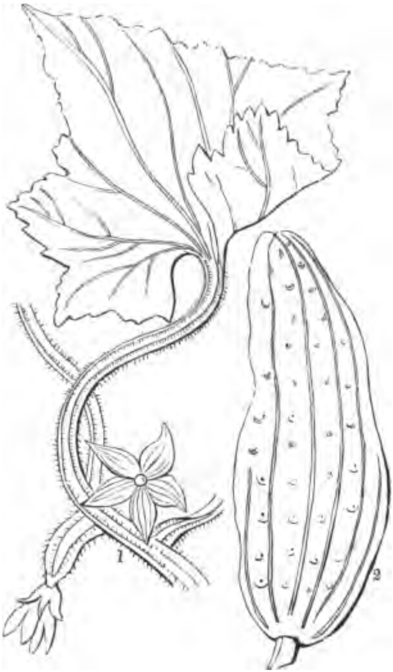


Fig. 869.

Fig. 868. Fruit of the Orange (*Citrus Aurantium*), cut transversely, showing the outer separable rind composed of epicarp and mesocarp, and the separable pulpy cells in the centre formed by the endocarp. The seeds are immersed in pulp in the endocarpial cells. The fruit is a peculiar kind of berry called Hesperidium. The calyx does not enter into its composition.

Fig. 869. Flowering stem, 1, and fruit, 2, of the Cucumber (*Cucumis sativus*). On the flowering branch the upper flower is male, the lower pendulous one female. The fruit is a peculiar bacca called a Pepo. Its rind is formed partly by the calyx, and it consists of three carpels, with parietal placentas according to some, and central placentas according to others. The Hebrew word *Kishuim* is translated cucumbers (Numbers xi. 5; Is. i. 8).

Fig. 870. The fruit of the Water-Melon (*Cucurbita Citrullus*). It is called a Pepo or Peponida, and resembles the Cucumber in structure. The fruit seems to be one of those included under the Hebrew word *Abattachim*, and translated Melons (Numbers xi. 5).

385. A *Pome* is a fleshy syncarpous fruit, composed of two or more scaly, or horny, or bony carpels, covered by a pulpy mass, which is incorporated with the calyx. The outer fleshy portion may be considered either as the combined epicarp and mesocarp, or it may be reckoned the receptacle enlarged, as in the Rose, and united to the calyx. This kind of fruit is seen in the Apple (Fig. 876), the Pear, the Quince, and the Medlar (Fig. 776, p. 267). There are frequently five carpels united, as seen in Figure 876. The cartilaginous cells enclosing the seeds of the Apple, and the bony coverings (nucules) of the seeds of the Medlar, may be reckoned either as the endocarp, or as the entire pericarp, according to the view taken of the formation of the pulpy exterior. In Apples we see little white downy lines running across the inner surface of the carpels; these, according to Berkeley, are formed by an hypertrophy, or increased growth of the cellular tissue.*

386. *Multiple or Collective Fruits* are formed by several flowers united, and the name anthocarpous is also applied, because they consist usually of the bracts and floral envelopes combined with the ovaries. They are either indehiscent or dehiscent, succulent or dry.

387. A *Cone* is a form of collective fruit, composed of scales or bracts covering one or more naked seeds (Fig. 877). Some consider these scales as carpels spread out, but from the absence of style and

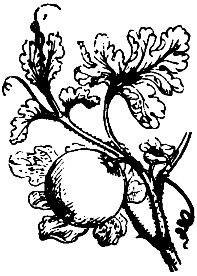
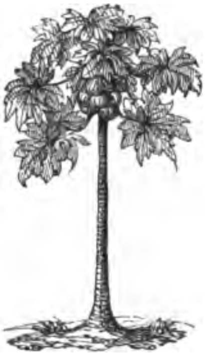


Fig. 871.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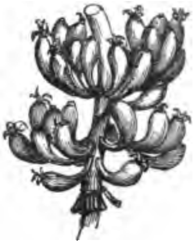
Fig. 873.

Fig. 871. Fruit of the Colocynth (*Cucumis Colocynthis* or *Citrullus Colocynthis*). It is called Coloquintida or Bitter apple. It is a Pepo or Peponida resembling the Cucumber in structure. It is the *Hunzal* of the Arabs, and it is one of the plants supposed to be included in the Hebrew word *Pakyoth*, translated Wild Gourds (2 Kings iv. 38–40). The Hebrew word *Pekaim*, translated *Knops* in 1 Kings vi. 18, and vii. 24, is supposed to refer to the form of the fruit of the Wild Gourd.

Fig. 872. Papaw-tree (*Carica Papaya*), bearing a cluster of fruit near the top of the stem. The fruit resembles a Pepo, but the calyx does not form part of it. The placentas are numerous and parietal.

Fig. 873. Fruit of the Banana (*Musa sapientum*). It is a succulent fruit allied to the Pepo. It is adherent to the calyx, and consists of three carpels with parietal placentas. The seeds are often abortive, especially when the fruit is good, as an article of diet.

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* See Gardener's Chronicle, December 1851.

stigma (Fig. 725, p. 250, and Fig. 766, p. 261), they seem more properly referable to floral leaves or bracts. The cone gives name to the natural order Coniferæ, or Cone-bearers, such as the Fir (Fig. 172, p. 72), Spruce, and Larch, the Cypress (Figs. 879 and 881), the Araucaria and Altingia (Fig. 59, p. 26). In the Juniper the scales of the cone are succulent (Fig. 880 and Fig. 273, p. 121), and the fruit has sometimes received the name of *galbulus*. In the Yew (Fig. 780, p. 267), the bracts enveloping the naked seed also become succulent.

388. In the Fig (Fig. 775, p. 266, and Fig. 782, p. 268) a multiple fruit occurs, consisting of numerous flowers enclosed in a hollow receptacle. What are called the seeds of the Fig, are in reality monospermous seed-vessels (achenes), with styles and stigmata. In the Mulberry (Fig. 878), Bread-fruit (Fig. 783, p. 268), Jack-fruit, and Pine-apple (Fig. 882), the ovaries and floral envelopes of several flowers are all united into one fleshy mass, placed on a more or less convex or elongated receptacle. The crown of the Pine-apple may be regarded as a series of empty bracts terminating the

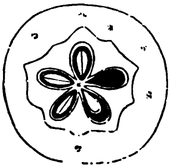
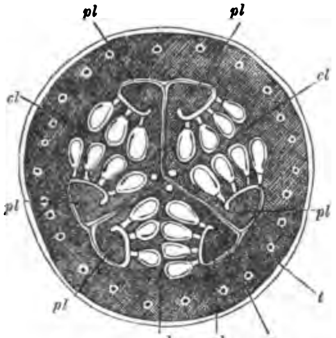


Fig. 876.



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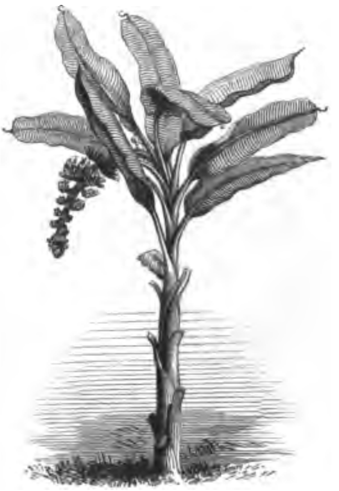


Fig. 875.

Fig. 874. Transverse section of the fruit of the Melon (*Cucumis Melo*), showing the placentas, *pl*, with the seeds attached to them. The three carpels forming the pepo are separated by partitions, *cl*. From the centre, processes, *s*, go to the circumference, *t*, ending in curved placentaries bearing the ovules. These placentas by some are considered as parietal, formed on the walls of the fruit, by others they are looked upon as the curved terminations of the central processes, *s*.

Fig. 875. Plant of Banana (*Musa sapientum*), with a fruit-bearing stalk hanging down from the upper part of the herbaceous stem.

Fig. 876. Section of the fruit of the Apple (*Pyrus Malus*), consisting of an epicarp and mesocarp partly formed by the calyx. A cartilaginous endocarp forming five cavities in the centre with seeds. The fruit is called a Pome. In the Medlar the endocarp is stony.

axis. In plants belonging to the same tribe, such as Bromelia Pinguin, the different flowers are separate, and do not unite into one mass when in fruit,—thus illustrating the composition of the Pine-apple. The succulent portion of the Mulberry is connected with the floral envelopes of several flowers; hence it is quite different from the Bramble, in which the succulent part is connected with the pericarp, and the fruit is formed by a single flower. In Figure 883, a section of the Mulberry fruit is given, showing the different flowers by which it is formed; and in Figure 884 is represented a separate female flower, with its ovary, styles, and stigmas. In the strobili of the Hop (Fig. 885), the bracts covering the flowers are membranous in place of being succulent.

389. *Transformations in Fruits.*—The same causes which produce alterations in the other parts of the flower, give rise to anomalous appearances in the fruit. The carpels, in place of bearing seeds, are sometimes changed into leaves, with lobes at their margin. In a monstrosity of a kind of Larkspur, Brongniart has shown the conversion of the seed-vessel

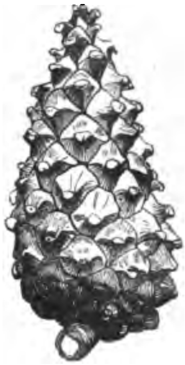
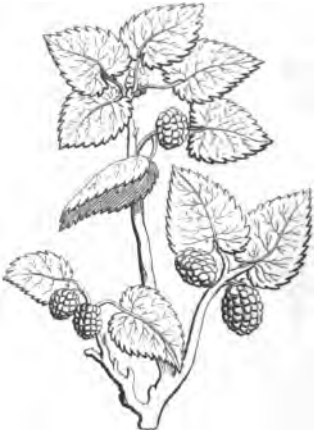


Fig. 877.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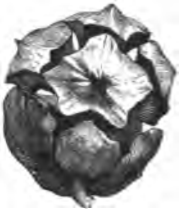
Fig. 879.

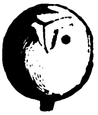
Fig. 880.

Fig. 877. Anthocarpous fruit of a Pine (*Pinus*), consisting of numerous hard scales covering winged seeds. These scales are bracts or floral leaves. The fruit is called a cone. It may be said to be a hardened female spike in the form of a collective fruit.

Fig. 878. Fruiting branch of black Mulberry (*Morus nigra*), which appears to be the *Sykaminos* or Sycamine-tree of the New Testament (Luke xvii. 6). The fruit is anthocarpous or collective and succulent. It consists of numerous flowers united together into a succulent mass. It is called a Sorosis.

Fig. 879. Anthocarpous or collective fruit of the Cypress (*Cupressus sempervirens*). It is a depressed cone formed by hardened scales covering naked seeds.

Fig. 880. Anthocarpous fruit of Juniper (*Juniperus communis*). It is a cone composed of succulent scales, which are united together into one mass, and cover the female flowers. The fruit is sometimes called a galbulus. Many think that, under the Hebrew terms *Eres* or *Æres* and *Berosh* several coniferæ were included, and especially some species of Juniper. The Juniper is the *Abhul* of the Arabs.

and seeds into leaves.* Similar changes have also been noticed by him in the fruit and seeds of the Rape, Soap-wort, and Scarlet Pimpernel. The production of leaves from the upper part of the fruit has been noticed in the case of the Pear (Fig. 430, p. 181). In the genus Citrus, to which the Orange and Lemon belong, it is very common to meet with a separation of the carpels, so as to produce what are called horned oranges and fingered citrons. In this case a syncarpous fruit has a tendency to become apocarpous. The same thing is observed in some species of the genus Nigella. In the Orange we occasionally find a supernumerary row of carpels produced, as shown in Figure 886, *el*, and these, when the fruit is completely formed, give rise to the appearance of oranges enclosed within the original one, as shown in Figure 887. The Navel Orange of Pernambuco is of this nature.

390. It sometimes happens that, by the union of flowers, double fruits are produced. The adhesion of two flowers does not necessarily imply sterility in the fruit. The ovary may be fertilized, and may come to perfection. In such a case, if the two pistils are adherent like the other parts of the flowers, then a double fruit is produced. Occasionally, however, a double fruit is produced, not by the incorporation of two

Fig. 881.

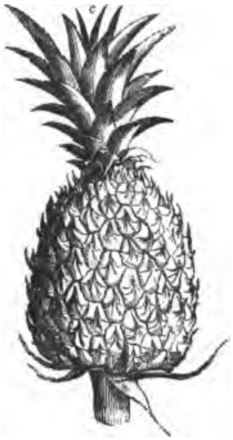

Fig. 882.

Fig. 881. Cypress-tree (*Cupressus sempervirens*), one of the cone-bearing plants yielding a collective fruit. The tree is by some considered as included under the term *Berosh*, which is translated Fir in many parts of Scripture (2 Sam. vi. 5; 1 Kings v. 8; 2 Kings ix. 23; Is. xiv. 8, &c.) The word *Tirzah* in Isaiah xliv. 14 has been translated Cypress, but there is no proof of this being the plant meant. Some think that Tirzah means the Evergreen Oak (Quercus Ilex). Some suppose that the *Etz Gopher* or Gopher-wood of the Bible (Gen. vi. 14) was the wood of the Cypress, or of some of the cone-bearing order.

Fig. 882. Fruit of the Pine-apple (*Ananassa sativa*), consisting of numerous flowers and bracts united together so as to form a collective or anthocarpous fruit. The crown of the Pine-apple, *c*, consists of a series of empty bracts prolonged beyond the fruit.

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* Brongniart, Monstruosités Vegetales. Archives du Museum, tom. iv. 43.

flowers, but by the abnormal development of a second carpel in the flower. In this way double Cherries are frequently formed. The state of the peduncle will often lead to a satisfactory conclusion as to the

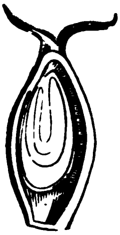

Fig. 884.

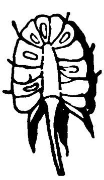

Fig. 883.

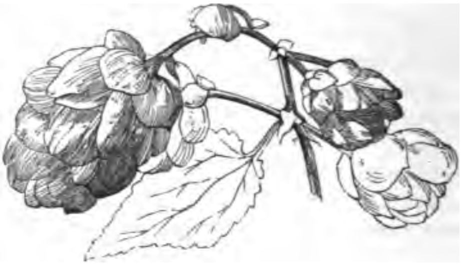

Fig. 885.

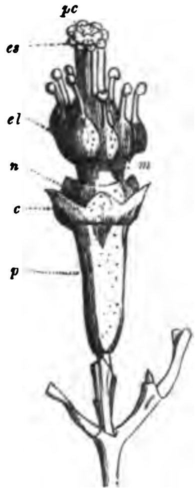

Fig. 886.

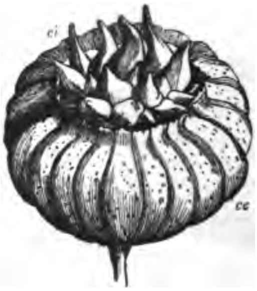

Fig. 887.

Fig. 883. Vertical section of the fruit of the Mulberry (*Morus nigra*), showing the various flowers of which it is composed, and which are all arranged on a common axis.

Fig. 884. One of the female flowers of the Mulberry (*Morus nigra*) separated, showing the seed, the embryo, and the styles.

Fig. 885. Fruit of the Hop (*Humulus Lupulus*), consisting of membranous scales covering female flowers. The fruit is called a Strobilus.

Fig. 886. An abnormal state of the Orange (*Citrus Aurantium*), in which supernumerary rows of carpels are produced, apparently from altered stamens; *p*, the peduncle which usually terminates the axis and bears the floral verticils, is prolonged beyond the calyx, *c*, and the annular disk, *n*, in the form of a distinct internode, *m*, bearing a circular group of stamens changed into carpels, *el*, with styles and stigmata. Within and above these there is another row of stamens changed into carpels, *es*, surrounding the central pistil, *pc*. In this instance all the carpels were sterile.

Fig. 887. Another monstrosity of the Orange, in which there are twenty external divisions, *ce*, representing carpels which, in place of uniting at the top, leave an opening, whence proceed twenty projections, *ci*, which form a crown to the fruit. These projections are a series of abortive carpels. Such fruits are called proliferous.

nature of double fruits. In the first-mentioned cases, the peduncle often shows a groove which marks the union of two; in the latter instance there is no such groove. Double Plums are sometimes produced by the development of an additional carpel, and double Oranges, Apples, and Cucumbers, are often the result of the adhesion of two flowers. Koenig mentions a Strawberry plant which produced eight strawberries on one stalk; and Turpin notices a Pine-apple with seven fruits united, the crowns of which remained free. Occasionally the multiplication of fruits may be traced to chorisis or splitting of parts. The production of leaves from fruits is by no means uncommon in the Pear, as already noticed, and in the cones of Pines, Spruces, and Larches, in which the axis becomes prolonged beyond the fruit.* Fruits producing leaves are usually more or less completely abortive, and they are called *frondiparous*.

391. The following may be given as a general arrangement of Fruits:—

I. APOCARPOUS FRUITS formed by one or more separate carpels.

1. Monospermal, containing one seed.

a. Dry and Indehiscent.

Achene or Achænium in Composite flowers; Caryopsis in Grasses; Nut in the Hazel, and in the Coco-nut Palm; Scaly Nut in Sagus; Aggregate Achenes or Achænia, numerous in Ranunculus and Rose, four in the Borage and Mint order. In some Achenes the pericarp is loose and separate from the seed, and they are called Utricles. Occasionally the calyx or perianth is closely applied to the Achene, as in Rumex. Some Legumes are dry, monospermal, and indehiscent, as Dipterix.

b. Succulent and Indehiscent.

Drupe in Cherry and Peach, and in Detarium; Aggregate Drupes form the Etærio of the Raspberry; Drupe with partitioned endocarp in the Tryma of the Walnut.

c. Dry and Dehiscent.

Some forms of Legume in which one seed only is developed, as in Copaifera, Cæsalpinia paniculata, and Geoffroya superba.

2. Polyspermal, containing usually more than one seed.

a. Dry and Dehiscent.

Follicle in Pæony; Legume in the Pea, and in Leguminous plants in general.

b. Dry and Indehiscent.

Some varieties of Legume, as in Cassia Fistula, and in Lomentum-bearing plants, such as Sophora tomentosa.

II. SYNCARPOUS FRUITS formed by two or more carpels united by their ovaries.

1. Monospermal, by abortion of one or more carpels or ovules.

To this head are referred many of the fruits included under the monospermal section of Apocarpous fruits, such as the Caryopsis of Grasses, the Nut, also the Samara of the Ash and Elm, and some varieties of Siliqua and Silicula, as in Sea-Kale and Woad.

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* See De Candolle's Organographie, pl. 36, fig. 3, and pl. 43, fig. 4.

2. Polyspermal.
   - *a.* Dry and Dehiscent.
     Capsule in Cotton, Mahogany, Poppy, Pyxis or Pyxidium in Henbane, Siliqua in Wallflower, Silicula in Shepherd's-purse; Ceratium in Celandine, Regma in Euphorbiaceous plants, Diplotegia in Campanula.
   - *b.* Dry and Indehiscent.
     Cremocarp of Umbelliferous plants, and Samara of Sycamore and Maples, in which the two carpels separate from each other, but do not truly dehisce.
   - *c.* Succulent and Indehiscent.
     - (1) *Baccate Fruits with Adherent Calyx.*
       The Bacca in Gooseberry, Pepo in Melon and Banana, Balausta in Pomegranate. Under this may be included also the Cynarrhodum in the Rose, the hep of which is formed by the succulent calyx enclosing the achenes.
     - (2) *Baccate Fruits with the Calyx not Adherent.*
       The Uva in the Grape, the fruit of Solanaceous plants such as the Potato, the Papaw fruit, the Hesperidium in the Orange, the Pome in the Apple and Pear, and the Nuculanium (a variety of Pome) in the Medlar.

III. ANTHOCARPOUS FRUITS formed by the union of several flowers.
   1. Succulent hollow receptacle enclosing monospermal ovaries produced by separate flowers, as in the Syconus of the Fig.
   2. Scaly spike of female flowers combined into one multiple fruit.
      - *a.* Scales hard and seeds naked in the Cone of the Fir.
      - *b.* Scales membranous, seeds in a seed-vessel, as in the Strobilus of the Hop.
   3. Succulent spike of female flowers, as in the Sorosis of the Mulberry and Bread-fruit.

392. *The Seed.*—When the ovule arrives at maturity it constitutes the seed, which is contained in a seed-vessel in the plants which are called *Angiospermous;* while, in *Gymnosperms*, such as Coniferæ (Fig. 766, p. 261), and Cycadaceæ, it is naked, or, in other words, has no true pericarpial covering. By far the larger number of flowering plants belong to the former division. It sometimes happens in Angiosperms, that the seed-vessel is ruptured at an early period of growth, so that the seeds become more or less fully exposed during their development; this occurs in Mignonette (Fig. 811, p. 274), where the capsule opens at the apex, and in Cuphea, where the placenta bursts through the ovary and floral envelopes, and appears as an erect process bearing the young seeds.

393. The seed (Fig. 888) consists of a nucleus, *c*, usually covered by two cellular integuments, *e* and *te*, which are sometimes included under the general name of *spermoderm.* The outer integument is denominated the *episperm, exosperm*, or more commonly the *testa* (Fig. 888, *te*). It corresponds to the primine of the ovule (Fig. 755, *p*, p. 256). It is frequently formed by a union of both primine

and secundine. It varies in its texture, being sometimes thin and membranaceous, at other times thick and hard. It presents various colours, being brown, white, red, black, and mottled. Its surface sometimes presents ridges and furrows, as in Larkspur (Fig. 889), reticulations, as in the Water Cress (Fig. 890), alveolar depressions, as in the Poppy (Fig. 891), and tubercular eminences, as in Chickweed (Fig. 892). Occasionally, the seminal integument is furnished with appendages in the form of wings, as in Pine seeds (Fig. 893) and Bignonia, or with a margin, as in Sandwort (Fig. 894); and at other times it

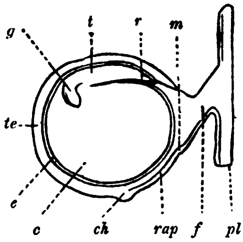


Fig. 888.

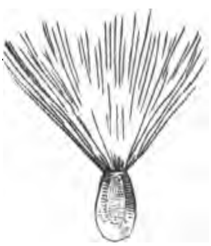


Fig. 895.

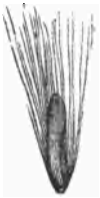
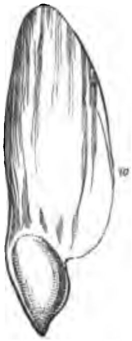


Fig. 896.



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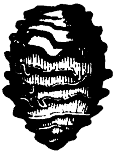


Fig. 889.

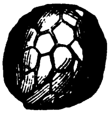


Fig. 890.

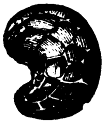


Fig. 891.

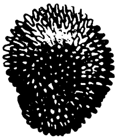


Fig. 892.

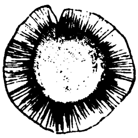


Fig. 894.

Fig. 888. The seed of the Pea (*Pisum*), deprived of one-half of its integument or spermoderm. The outer covering, called epicarp, exocarp, and testa, is marked *te*, the inner, called endocarp, *e*. Within these integuments is the nucleus, consisting of cotyledons or seed-lobes, *c*, containing nourishing matter, the gemmule, or young leaf-bud, *g*, the radicle, or young root, *r*, the tigelle or stalk between root and bud, *t*. The seed is attached to the placenta, *pl*, by a cord or funiculus, *f*. The nourishing vessels, *rap*, enter the nucleus at the chalaza, *ch*, and the root of the embryo points to the micropyle or foramen, *m*.

Fig. 889. Obovate seed of the Larkspur (*Delphinium*), the spermoderm or testa of which presents wavy ridges and furrows.

Fig. 890. Round seed of the Water-Cress (*Nasturtium*), with a reticulated testa or exosperm.

Fig. 891. Kidney-shaped seed of the Poppy (*Papaver*), with alveolar depressions on its surface. The testa is said to be alveolar or pitted.

Fig. 892. Rounded seed of Chickweed (*Stellaria*), having tubercular eminences on the surface of the episperm or exosperm.

Fig. 893. Seed of Fir (*Pinus*), with a membranous appendage, *w*, to the testa, called a wing. The seed is said to be winged.

Fig. 894. Seed of Sandwort (*Arenaria*), with a margin or border round it. The seed is called marginate or bordered.

Fig. 895. Seed of Asclepias, with a cluster of hairs arising from the edges of the micropyle, and by some considered as a hairy aril. These hairs are for the purpose of scattering the seed.

Fig. 896. Hairy or comose seed of the Willow (*Salix*). The hairs arise from the short funiculus, and surround the seed.

is provided with hairs, as in the Cotton plant (Fig. 101, p. 44), Asclepias (Fig. 895), and the Willow (Fig. 896). It is of importance to distinguish between such hairs and the pappus of Composite plants (Fig. 495, p. 198), and of Valerian (Fig. 497, p. 198), which is in reality an abortive calycine limb attached to the fruit. We have already stated that the presence of the style or stigma distinguishes single-seeded fruits from seeds.

394. The seed of some Polemoniaceous plants has a covering, consisting of small cells or hairs containing spiral fibres inside. These hairs are closely applied to the surface of the episperm, and are confined by a mucilaginous coating. When placed in water, the mucilage dissolves, and the hairs are liberated, so as to spread out in all directions. The walls of the cells are also usually ruptured, so as to allow the spiral fibres to uncoil, and form a beautiful object under the microscope. The same kind of structure occurs in the pericarpial covering of some Labiate plants, such as Salvia, and of some Composite plants, such as Senecio (¶ 39). The spreading out of these fibrous cells is apparently intended for the purpose of fixing the seed in the moist soil, into which they are carried by the wind. Sometimes the secundine of the ovule assumes a succulent consistence in the seed, and forms a lining to the episperm.

395. The *Endopleura* or *tegmen* is the inner seminal envelope or integument. . In general, it is formed from the tercine or the membrane of the nucleus, and it is sometimes united with the embryo-sac (Fig. 757, *s*, p. 259). In some cases, as in the Water-lily, Ginger, and Pepper, this sac remains as a distinct covering of the young plant under the name of the vitellus. The endopleura is often incorporated with the testa, and scarcely separable from it. It is composed usually of a thin layer of cellular tissue, and when the nucleus is sinuous, as in the Walnut (Fig. 897), it follows its windings, so as to enter between the lobes.

396. The spermoderm, or general seminal integument, has certain markings corresponding to those mentioned in the ovule. Thus, we observe the micropyle or small opening in the coats which extends to the nucleus (Fig. 888, *m*), the chalaza (Fig. 888, *ch*) or the fibro-vascular connection between the nucleus and the coats, and the base or hilum by which the seed is connected with the funiculus (Fig. 888, *f*). These bear the same relation to each other as they do in the ovule. Thus, in an orthotropous seed, the hilum and chalaza are united, and the micropyle is at the opposite end or apex; in a campylotropous seed, the hilum and chalaza are united, and the micropyle is slightly removed from the hilum; while in an anatropous seed, the nucleus is inverted—its base and the chalaza being removed from the hilum, and the micropyle being close to the hilum. The seed of the Orange is anatropous, and the brown chalaza, *c*, is seen in Figure 898 as an expansion at one end, while the raphe connecting the hilum and chalaza is seen in Figure 899 running as a border, *r*, along one side of the seed.

397. The micropyle is smaller and less distinct in the full grown seed than it was in the ovule. It indicates the place where the radicular extremity of the embryo is situated (Fig. 906, *r*, p. 302). Its situation in the Bean and Pea, when they begin to sprout, is marked by a little lid-like process which is pushed upwards. The chalaza is more or less evident in different seeds. It is conspicuous in anatropous seeds, such as the Orange (Fig. 898), where the raphe (Fig. 899, *r*) or vascular connection between it and the placenta exists. The raphe forms a cord usually along the inner side of the seed, and may be considered as a prolongation from the funiculus, along with a covering derived from the integument of the seed.* The scar or hilum is of different sizes and colours, and indicates the base of the seed or the

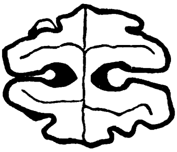


Fig. 897.

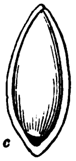
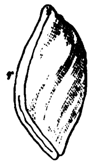


Fig. 898.



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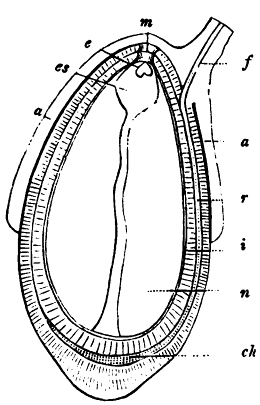

Fig. 900.

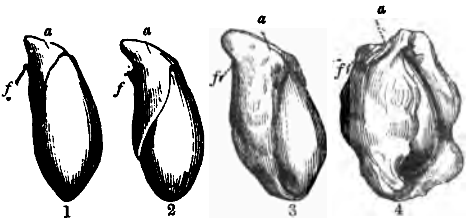

Fig. 901.

Fig. 897. Seed or kernel of the Walnut (*Juglans*) cut transversely, showing the divisions which correspond to hard processes of the endocarp or shell. The seed is four-lobed at its apex and base, and is exalbuminous. The integuments follow the windings of the cotyledons, which resemble the convolutions of the brain. The cotyledons are fleshy and oily.

Fig. 898. Anatropal seed of the Orange (*Citrus Aurantium*) opened to show the chalaza, *c*, which forms a brown spot at one end.

Fig. 899. Entire anatropal seed of the Orange (*Citrus*), with its rugose or wrinkled testa, and the raphe or internal funiculus, *r*, ramifying in the thickness of the testa on one side.

Fig. 900. Young anatropal seed of the White Water-lily (*Nymphæa alba*), cut vertically. It is attached to the placenta by the funiculus or umbilical cord, *f*, cellular prolongations from which form an aril, *a a*. The vessels of the cord are prolonged to the base of the nucleus, *n*, by means of the raphe, *r*, composed of cells and spiral vessels. The base of the nucleus is indicated by the chalaza, *ch*, while the apex is at the micropyle, *m*. The covering of the seed composed of episperm and endopleura, or, in other words, of exosperm and endosperm, is marked *i*. The nucleus, *n*, is composed of albumen or perisperm, surrounded by its covering, and enclosing the embryo-sac, *es*, which remains in the ripe seed in the form of a vitellus. The embryo, *e*, with its suspensor, is contained in the sac, the radicle pointing to the micropyle, *m*.

Fig. 901. Successive stages in the development of the arillode, the false or micropylar aril, of the Spindle-tree (*Euonymus*). The foramen or micropyle, *f*, is the part whence the arillode, *a*, proceeds. It passes through different stages, from 1, where it covers only a small part of the seed, to 2 and 3, where the covering is extended, until it reaches 4, where the seed is almost entirely enveloped by it.

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* A full description of these parts has already been given when treating of the ovule, p. 258.

place where it is attached to the placenta. This attachment is either direct, or is accomplished by the intervention of a stalk or cord called the funiculus, which in Magnolias becomes much elongated. In the Bean the scar is of a black colour; in other cases it is white or brown. It sometimes extends over a large portion of the seed, as in the Horse Chestnut.

398. On the outside of the integument of the seed there is sometimes an additional partial covering of a cellular nature which is developed after the ovule is fertilized, and which has received the name of *aril* (arillus). It proceeds from the placenta or top of the funiculus in some instances, while in others it arises from the foramen of the seed. In the former case it is called a true or funicular aril, while in the latter it is called a false or micropylar aril, or sometimes *arillode.* In the Passion-flower and Water-lily (Fig. 900, *a*), a funicular aril exists, while in the Spindle-tree, Nutmeg, Spurge (Fig. 830, p. 280), and Milk-wort, a micropylar aril is seen. In Figure 901, a representation is given of the development of the arillode, *a*, in the Spindle-tree, *f* being the foramen or micropyle from which this seminal covering arises. It finally spreads as a beautiful scarlet envelope of the seed. In the Nutmeg, the arillode is laciniated and of a fine scarlet colour, constituting the mace. Some consider the hairs of the seed of Asclepias (Fig. 895, p. 297) as a form of micropylar aril. Certain cellular processes are occasionally seen at the base, apex, or sides of the seed. They have received the names of *caruncles* and *strophioles.* In Milk-wort they occur at the base, in the Castor-oil seed at the apex, and in Blood-root and Asarabacca they constitute a lateral crest arising from the raphe. Some have included all these under the name aril, applying the terms raphian and chalazal according to their position.

399. The different parts of a seed are represented in Figure 900, *n* being the nucleus or central portion, composed of nourishing matter enclosing the embryo-sac, *es*, with the embryo-plant, *e*, the radicle of which points to the micropyle, *m ; f*, the funiculus, *ch*, the chalaza, *r*, the vessels running from the placenta to the base of the nucleus, *i*, the integuments or spermoderm, and *a a*, the funicular aril.

400. The nucleus or kernel of the seed (Fig. 900, *n*) is the fully developed central portion of the ovule. It is much altered in general by the deposition of starchy, azotised, and ligneous matter, and by the development of the embryo. It consists either of the embryo alone, as in Wallflower (Fig. 902), or of the embryo, along with a separate deposit of nourishing matter called the *albumen* or *perisperm*, as in Palms (Fig. 903). This albumen consists of starchy, ligneous, oily, saline, and nitrogenous substances contained in cells of various consistence. It is, therefore, not merely what chemists call vegetable albumen ; and hence it is better to give it the name of perisperm or endosperm.

401. A seed is said to be *albuminous* or perispermic when it has a separate store of albumen distinct from the embryo, as in the Coco-nut (Fig. 904), Wheat (Fig. 846, p. 283), and Aconite (Fig. 905); and *exalbuminous* or aperispermic when the nutritious matter is incorporated with the lobes of the embryo, as in Cruciferous plants (Fig. 902), in the Bean, the Pea (Fig. 888, p. 297), Almond, and Maple. In the last mentioned cases, the lobes or cotyledons (¶ 75) of the embryo are thick and fleshy, in consequence of the nourishing matter which they have absorbed, and the embryo occupies the entire cavity of the seed.

402. The perisperm varies in its consistence according to the nature of the deposit and the state of the cells. In the Vegetable-Ivory Palm, the cells are thickened by ligneous deposits, and the perisperm is of a horny consistence, so also in Coffee (Fig. 854, p. 285). In the Cereal grains, as Wheat (Fig. 846, p. 283), it is mealy and farinaceous; in the Poppy it is oily; in the Coco-nut (Fig. 904, *p*) it is cartilaginous; in the Mallow, mucilaginous. When cut, the perisperm may present a uniform appearance, as in Castor-Oil, or it may have a mottled or *ruminated* appearance, as in the Nutmeg and Betel-nut. The latter depends on some unaltered cells of the endopleura or of the embryo-sac ramifying through the substance and forming convolutions. The proportion which the perisperm bears to the embryo varies much. Sometimes, as in the Coco-nut (Fig. 904), in the Date and in Monkshood (Fig. 905), the embryo is very small, while the albumen is abundant; at other times, as in the Nettle (Fig. 906), the embryo is large and the albumen small. The deposit of

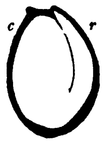


Fig. 902.

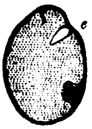
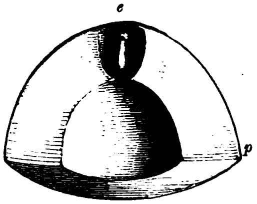


Fig. 903.



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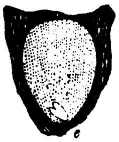

Fig. 905.

Fig. 902. Seed of Wallflower (*Cheiranthus*) cut vertically. The seed is exalbuminous or aperispermic—all the nourishing matter being incorporated with the cotyledons, *c*. On removing the integument which is marked by the dark lines, the embryo alone is found in the interior. The radicle, *r*, is folded on the edges of the cotyledons, which are accumbent; the plant belongs to the division of cruciferæ, called Pleurorhizeæ.

Fig. 903. The seed of a Palm, cut vertically, showing copious horny albumen, and a small embryo, *e*, at one side. The seed is albuminous or perispermic, having a store of nutriment separate from the embryo.

Fig. 904. Section of a part of the seed of the Coco-nut (*Cocos nucifera*), showing the abundant cartilaginous albumen or perisperm, *p*, and the small embryo, *e*, in a cavity at one end of the seed, close to the part of the endocarp which is perforated, and remote from the hilum or base of the seed.

Fig. 905. The seed of the Monkshood (*Aconitum*), with its covering or spermoderm, its copious albumen, and a small embryo, *e*, at one extremity. The seed is albuminous, and the embryo is slightly transverse in its position.

albumen takes place within the integuments of the seed. It either occupies the space between the endopleura and the embryo-sac (Fig. 900, *n*, p. 299), when it is called *exospermic*, as in the Water-lily (Fig. 907) and other plants which have a distinct vitellus, or it is deposited within the sac, and then is *endospermic;* or it occupies both positions at once, and then may be called by the general name of perisperm.

403. *The Embryo* is the young plant contained in the seed. It is the part to the production and nourishment of which all parts of the flower contribute. It is contained originally in a cavity called the embryo-sac (Fig. 900, *es*), and appears at first as a small vesicle or cell (Fig. 900, *e*), attached to the sac by a cellular process called a suspensor, which is often very long, as in Cruciferous plants (Fig. 910). The suspensor (Fig. 910, *s*) sometimes presents a peculiar enlarged nucleated cell, *c*, at the extremity opposite to the embryo, *e*. The embryo-sac is sometimes separated from the endopleura by a quantity of perisperm (Fig. 900, *n*), at other times it is incorporated with it. The embryo-sac exhibits peculiar tubular prolongations from its base and apex in some instances, as in the Eyebright.*

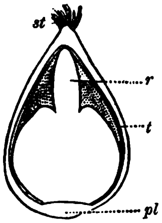

Fig. 906.

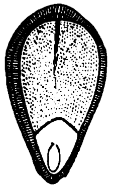

Fig. 907.

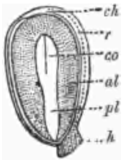

Fig. 908.

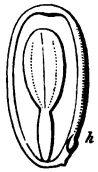

Fig. 909.

404. The Embryo in its structure exhibits cells and spiral vessels. It consists of a general axis, one part of which is concerned in the

Fig. 906. Vertical section of the achene of the Nettle (*Urtica*), containing the single seed, with its integuments or testa, *t*. All outside *t* belongs to the fruit, which bears the penicillate stigma, *st*. The seed is erect, being attached by its base to the placenta, and its apex or foramen being at the opposite extremity. The embryo is consequently inverted, as its radicle or base, *r*, points to the foramen, while its apex or the cotyledons are at the base of the seed. The radicle is called superior as it points in this case to the summit of the seed-vessel. There is only a small quantity of separate albumen, the embryo occupying nearly the whole interior of the seed.

Fig. 907. The seed of the White Water-lily (*Nymphæa alba*), cut vertically, showing the integuments, the albumen and the embryo-sac, and the embryo. The greater part of the albumen or perisperm is outside the embryo-sac, but there is some also within it, and called endospermic. The remains of the embryo-sac form the vitellus containing the embryo.

Fig. 908. The seed of the Pansy (*Viola tricolor*) cut vertically. The embryo, *pl*, is axial, in the midst of fleshy albumen, *al*. The seed is anatropal, and the embryo is orthotropal, the cotyledons, *co*, point to the base of the nucleus or chalaza, *ch*, while the radicle, or the other extremity of the embryo, points to the foramen, close to the hilum, *h*. The hilum or base of the seed, and the chalaza or base of the nucleus, are united by means of the raphe, *r*.

Fig. 909. Anatropal seed of Barberry (*Berberis*), with its erect or orthotropal embryo. The cotyledons of the embryo show venation, as indicated by the lines on them. The radicle or narrow end of the embryo points to the micropyle, close to the hilum or base of the seed, *h*, The embryo is in the midst of albumen.

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* See Tulasne, Etudes d' Embryogenie Vegetale, Annales des Sciences Nat. 3d ser. Bot. xii. 21, 321.

production of the root (Fig. 908, *pl*), and another in the formation of the stem (Fig. 908, *co*). The radicle or root-portion of the axis always points to the micropyle of the seed. Hence, in orthotropal seeds (Fig. 906), the embryo is said to be inverted, because its radicle points to the apex of the seed where the micropyle is situated, while in anatropal seeds (Fig. 909) it is erect. The axial portion of the embryo is provided with foliaceous or fleshy organs called seed-leaves, or *cotyledons* (Fig. 908, *co*), which serve a temporary purpose in nutrition. Their venation is seen in Figure 909. From the upper part of the axis, the stem called the *plumule* rises, bearing the ordinary, or *primordial* leaves of the plant. These separate parts are well seen when the young plant has begun to grow, as in Figure 911, where *t* is the general axis, with the roots *r* at the base, the cotyledons, *c c*,

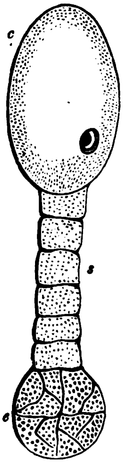


Fig. 910.

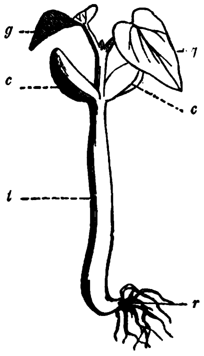


Fig. 911.

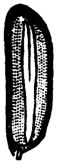


Fig. 913.

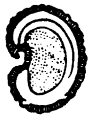


Fig 915.

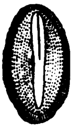


Fig. 912.

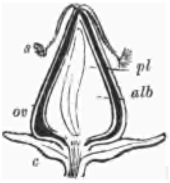


Fig. 914.

Fig. 910. The embryo of the Whitlow-grass (*Draba verna*), with its suspensor. The embryo, *e*, consists of a globular mass of cells which shows the original four divisions, each of which divides into two, till, by successive cell-multiplication, the embryo is formed. The suspensor consists of a series of cells, *s*, ending a large terminal nucleated cell, *c*, at the micropyle. This cell is three times the diameter of the embryo at the same period, and seems to serve the purpose of nutrition.

Fig. 911. Embryo of the Haricot (*Phaseolus vulgaris*) sprouting, showing the radicular portion, *r*, giving off roots, the two cotyledons or seed-leaves, *c c*, with the portion of the axis, *t*, between the root and cotyledons. The axis or plumule arises from between the cotyledons bearing the first ordinary, or primordial leaves, *g g*. The embryo is dicotyledonous, and the cotyledons epigeal, appearing above ground during sprouting.

Fig. 912. Seed of the Scarlet Pimpernel (*Anagallis arvensis*), cut vertically, showing the embryo with its two cotyledons and radicle in the axis of albumen. The embryo is said to be axile or axial.

Fig. 913. Axial embryo of the Barberry (*Berberis*), shown in a vertical section of the seed.

Fig. 914. Fruit (Achene) of the Dock (*Rumex*), cut vertically, showing the embryo, *pl*, at one side of the albumen, *alb*. The embryo is said to be abaxial or eccentric, and it is slightly curved. The covering of the fruit is marked *ov*; the stigmas and styles, *s*, are attached to it. All within the pericarpial covering is the seed. The remains of the perianth or calyx are marked *c*.

Fig. 915. Seed of the Red Campion (*Lychnis*), cut vertically, showing the peripherical embryo, with its two cotyledons and its radicle. The embryo is curved round the albumen, so that its cotyledons and radicle both come near the hilum. The embryo is sometimes called amphitropal.

above, and the plumule with the primordial leaves coming from between the cotyledons.

405. The Embryo is sometimes placed in the centre of the albumen, or in the axis of the seed, and in a straight direction (Figs. 912 and 913), it is then *axile* or *axial;* when not in the centre of the seed it is *abaxile* or *eccentric* (Fig. 914). In place of being straight it is often curved in various ways. This may depend on the curvature of the seed itself, as in the Snake-nut, and in Campylotropous seeds (Fig. 888, p. 297); or the seed may be straight, and the embryo alone curved. In the Chickweed order (Fig. 915), and in the Marvel of Peru (Fig. 916), the embryo is curved round the albumen, becoming *peripherical.* In other cases, as the Thorn-apple (Fig. 917), it is curved in a similar way within the albumen. In Grasses it is situated at the base of the seed, and outside the albumen (Figs. 846 and 848, p. 283). In the Poppy, the embryo is in the axis, but is *curved* or *arcuate* (Fig. 918), in Geranium, the cotyledons are twisted and doubled, in Convolvulus, they are corrugated, and in the Potato and in Bunias (Fig. 919), they are spiral. In some Cruciferous plants, the cotyledons are bent like a leaf folded laterally on its midrib, and they are then called *conduplicate*, and marked o≫; in other Cruciferous plants, they are flat, and the radicle is either bent along their edges, as in Wallflower (Fig. 920), and marked o=; or lies on the back of one of them, as in Rocket (Fig. 921), and marked o ||. In the former case, the cotyledons are *accumbent*, in the latter, *incumbent.* Some authors speak of the position of the embryo, not merely in reference to the seed, but also in reference to the fruit. This is apt to lead to confusion. A superior or ascending radicle is the name given by them when it points to the apex of the fruit (Fig. 906, p. 302, and Fig. 914), while an inferior or descending radicle points to the base

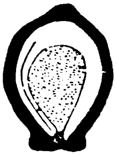
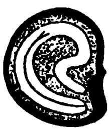


Fig. 916.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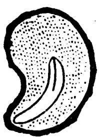
Fig. 918.

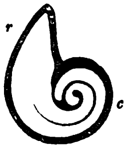

Fig. 919.

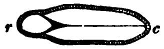

Fig. 920.

Fig. 916. The seed of the Marvel of Peru (*Mirabilis*), cut vertically, showing the amphitropal or peripherical embryo, surrounding the albumen. The cotyledons and radicle are close to the hilum.

Fig. 917. Curved embryo of the Thorn-apple (*Datura*), with its twisted radicle. In this case the embryo does not surround the albumen, but is curved within it. The cotyledons and radicle point to the hilum.

Fig. 918. Vertical section of the seed of the Poppy (*Papaver*), showing the embryo in the axis of the albumen, but slightly curved or arcuate (like a bow).

Fig. 919. Vertical section of the seed of Bunias, with its spiral embryo. The cotyledons, *c*, are rolled upon the radicle, *r*, in a spiral manner; hence the name Spirolobeæ.

Fig. 920. Transverse section of the seed of the Wallflower (*Cheiranthus*). The radicle, *r*, is folded on the edges of the cotyledons, *c*, which are said to be accumbent. The radicle is lateral hence the name Pleurorhizeæ.

of the fruit; a centripetal radicle points to the centre or axis of the fruit, while a centrifugal one points in the opposite way.

406. In some plants, the embryo is entirely cellular and has no cotyledons. They are denominated *Acotyledonous*. They correspond to Cryptogamic or flowerless plants. The embryo, in such cases, is called a *spore* (Fig. 922). It gives off roots and stems from different parts of its surface, and not from any fixed points. It may either be regarded as an ovule remaining in a cellular state, or as a simple cellular embryo. It will be noticed when treating of the organs of Cryptogamic plants.

407. Plants which possess cotyledons in their embryo (Fig. 923) are called *Cotyledonous*, and they are divided into those having two cotyledons, and which are called *Dicotyledonous*, and those having one,

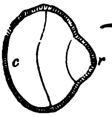

Fig. 921.

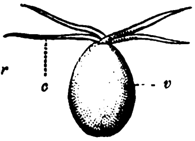

Fig. 922.

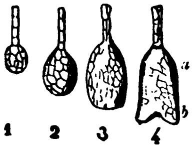

Fig. 924.

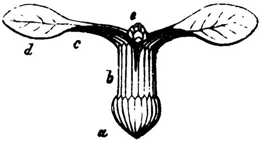

Fig. 925.

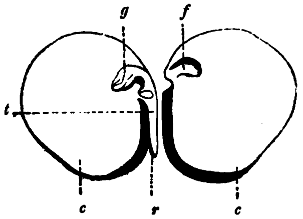

Fig. 923.

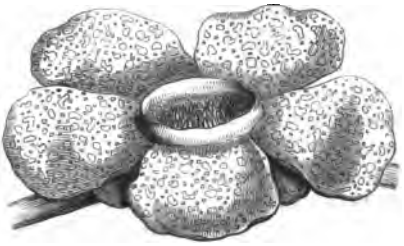

Fig. 926.

Fig. 921. Transverse section of the seed of the Dames-Violet (*Hesperis*). The radicle, *r*, is folded on the back of the cotyledons, *c*, which are said to be incumbent. The radicle is dorsal; hence the name Notorhizeæ.

Fig. 922. Cellular spore, *v*, of Vaucheria, which may be considered a cellular embryo without cotyledons (acotyledonous). There are no definite points whence the root and stem proceed. The spore in the present instance is furnished with filamentous processes, *c*, called cilia.

Fig. 923. Embryo of the Pea (*Pisum*) laid open to show its different parts. This embryo occupies the whole interior of the seed. It consists of two fleshy cotyledons, *c c*, the axis, *t*, with the radicular extremity, *r*, and the plumular end, *g*, often called the gemmule. The depression in one cotyledon, where the plumule lay, is marked *f*. The embryo is dicotyledonous, and the cotyledons are hypogeal, remaining below ground when the plant sprouts or germinates.

Fig. 924. A dicotyledonous embryo, in different stages of development, within the seed. At 1 it appears as a globular cellular mass at the extremity of a cellular cord or suspensor; at 2 it becomes more ovoid; enlarges still more at 3; and at 4 it presents two distinct portions, *a*, the radicle attached to the suspensor, and *b* the two cotyledons.

Fig. 925. Ideal representation of a dicotyledonous embryo or bifoliar phyton, with its radicular extremity, *a*, its two cotyledons, *d c*, with their sheathing bases embracing the axis, *b*, and the primary bud, *e*. A dicotyledonous plant may be considered as composed of a series of such bifoliar phytons.

Fig. 926. Flower of Rafflesia, a parasitic plant found in Java. The flower is three feet in diameter, and its cup can contain nearly twelve pints of fluid. Its seeds resemble the spores of Cryptogamic plants. Its embryo has no cotyledons. Hence Lindley calls it a Sporogen.

called *Monocotyledonous.* The former correspond with the Exogenous division of Phanerogamous or flowering plants, the latter with the Endogenous. A dicotyledonous embryo at first appears in the form of a cell (Fig. 900, *e*, p. 299), the production of which in the embryo-sac depends on the application of the pollen to the stigma. This cell is nucleated, and developes others in succession (Fig. 910, *e*) until the embryo assumes the appearance of a congeries of cells suspended by a cellular filament (suspensor), as shown in Figure 924, 1. The globular cellular mass becomes afterwards more elongated, and passes through the stages 2 and 3 of Figure 924 until it assumes the appearance seen at 4, having an oblong or cylindrical form, with one extremity, *a*, undivided, and the other, *b*, lobed or notched. The undivided portion is the radicle (young root), and it may be considered as part of the rudimentary axis, from one end of which the roots are given off, and from the other the primary bud or plumule. The split portion of the embryo is composed of two lobes or cotyledons, formed at one node, and placed opposite to each other.

408. The cotyledons vary in their consistence, being sometimes leafy, at other times fleshy (Fig. 923). They are sometimes so large as to form the great bulk of the seed, as in the Bean, Pea (Fig. 888, p. 297), and the Almond. They form the first bud of the axis, which may thus be said to consist of a radicular and cotyledonary portion—their point of union being the *collar*, *neck*, or crown. The part interposed between the neck and the cotyledons, which is often very short, is sometimes called the *cauliculus* or *tigellus.* The dicotyledonous embryo then is composed of two-leaves or two unifoliar *phytons*, as they are called, united together so as to form one axis. The sheathing lower part of the cotyledons helps to form the caulicule; and from the axil of the cotyledons, or from the axis between them, is produced the plumular or gemmular bud (Fig. 923, *g*) which forms the stem and leaves. This embryo may be represented by the ideal Figure 925, in which *b* is the axis or tigellus, *a*, the radicular portion, connected with the soil and darkness, *d*, the two cotyledons, united at their lower part so as to form the tigellus, and *e*, the primary bud or plumule, connected with air and light. The embryo may be called a bifoliar phyton.

409. Although this is the usual state of the embryo in Exogens, nevertheless, there are a few exceptions. In some Exogens without leaves, as the Dodder (Fig. 128, p. 54) and Rafflesia (Fig. 926), the cotyledons are also suppressed. The embryo of these plants (Fig. 927) has a resemblance to the spore of Acrogens. In Cone-bearing plants, as the Pine, Spruce, Fir, and Cedar, the cotyledons are split by collateral chorisis, so as to be divided into several (Fig. 928), and this has given rise to the term *polycotyledonous* applied to them. The cotyledons of the Geranium and Lime-tree (Fig. 929) are divided into lobes. Accidental divisions are also seen in the cotyledons of the Sycamore and Rue. In Schizopetalon and some other

Cruciferæ, the cotyledons are usually bipartite, so as to appear to be four.*

410. A monocotyledonous differs from a dicotyledonous embryo in having only one cotyledon or seed-leaf (Fig. 930, *c*). It is composed

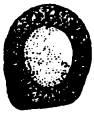

Fig. 927.

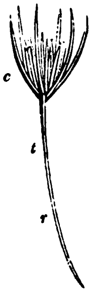

Fig. 928.

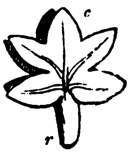

Fig. 929.

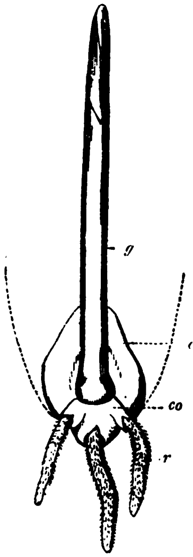

Fig. 930.

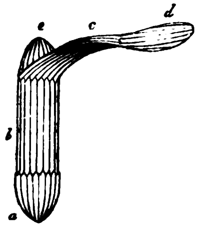

Fig. 932.

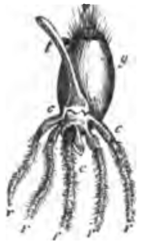

Fig. 931.

Fig. 927. Acotyledonous embryo of the Dodder (*Cuscuta*). There is a simple thread-like curved axis, but no cotyledons.

Fig. 928. Polycotyledonous embryo of the Pine (*Pinus*) beginning to sprout. The axis, *t*, shows its radicular portion, *r*, and cotyledonary portion, *c*. The cotyledons, *c*, appear to be numerous, but this is considered as being produced by the chorisis or division of two. Within the cotyledons the primordial leaves are seen, constituting the plumule or first bud of the plant.

Fig. 929. Embryo of the Lime-tree (*Tilia*), with its radicle, *r*, and its palmately five-lobed cotyledons, *c*.

Fig. 930. Monocotyledonous embryo of the Oat (*Avena*) sprouting. The radicular extremity of the axis gives off a number of rootlets, *r*, which pass through sheaths, *co*, the single cotyledon is marked *c*, the young stem *g*. The edges of the grain (caryopsis) are marked by the dotted lines.

Fig. 931. Grain (caryopsis) of Wheat (*Triticum*) sprouting. The embryo occupies the lower part of the grain, *g*. The radicular portion of the axis gives off roots, *r r*, which pass through sheaths, *c c*, while the primary bud or plumule, *t*, rises with its single sheathing cotyledon or seed-lobe. The embryo is monocotyledonous. The great mass of the grain is made up of farinaceous albumen or perisperm.

Fig. 932. Ideal representation of a Monocotyledonous or unifoliar phyton. The axis, *b*, has a radicular extremity, *a*, and a plumular bud, *e*. The cotyledon, *d c*, has a sheathing base embracing the axis, and giving off the plumular bud, *e*, from its axil. A monocotyledonous plant may be considered as composed of a series of such phytons.

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* See Duchartre, Memoires sur les embryons qui ont été décrits comme polycotylés. Ann. des Sc. Nat. 3 ser. Bot. x. 207.

of an axis (Fig. 931) having a radicular portion, *r*, and a cotyledonary portion, *t*, and it may be represented by a single leaf or a unifoliar *phyton*. In Figure 932 is given an ideal representation of a monocotyledonous embryo, with its tigellus or axis, *b*, having a radicular portion, *a*, one cotyledon, *d c*, with a sheathing base, and a bud in its axil, *e*, which rises as the stem. When this embryo is examined in the seed, it frequently exhibits no marked divisions—the cotyledon being coiled round the axis like a sheath, and embracing the plumule so as to conceal it. This is the case with the embryo of the Coco-nut (Fig. 904, p. 301). In some cases, as in the Cuckow-pint (Fig. 158, p. 67), there is an evident slit on one side of the cotyledon, indicating the point where the plumule protrudes when sprouting. Sometimes a monocotyledonous embryo has more than one cotyledon. In that case, the second cotyledon alternates with the first, being produced at a second node, which is separated from the first by an internode.

411. *Transformations in Seeds.*—Changes take place in seeds by abortion, degeneration, and union. There are few plants in which all the ovules become perfect seeds. Many are suppressed during the progress of growth, so that frequently one seed is developed at the expense of several ovules. Sometimes the seeds are converted into leaves. Brongniart has noticed this in a specimen of the Chinese Primrose, in which the anomalous seeds attached to the central placenta resembled the leaves of the plant in their form, while, at the same time, the parts of the calyx and corolla were slightly modified.* He has also described and figured the foliar transformation of ovules and seeds in Delphinium elatum, Brassica Napus, Soapwort, and Scarlet Pimpernel.† Turpin has observed the seeds of Columbine, of Dutch Clover, and of the Carrot, transformed into leaves. Monstrosities sometimes occur by the union of seeds.

412. There is usually a single embryo in each seed, but cases occur in which a plurality of embryos is produced. This is a very common occurrence in the Orange, Cycas, and Cone-bearing orders. In the case of the two latter orders, the suspensor often ramifies so as to produce numerous separate embryos on its branches. These embryos are frequently abortive. In the seed of the Fir there are certain cellular bodies, called corpuscles by Brown, which give origin to filaments by which the embryos are suspended. These may be said to resemble the large cell at the upper part of the suspensor in some Cruciferous plants (Fig. 910, *c*, p. 303). Accidental union of embryos also takes place. De Candolle observed double embryos in the Cress, and in species of Spurge and of Mustard. The appearance of three or four cotyledons in the seeds of some species of Solanum and in the Haricot, has been traced to a union of embryos, and not to a chorisis of two cotyledons.

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* Annales des Sciences Nat. 2d ser. i. 310.

† See Brongniart sur Monstruosités Végétales, in Archives du Museum, iv. 43.

413. Recapitulation of the chief facts relative to the Fruit, Seed, and Embryo:—

1. The Fruit consists either of the ovary alone arrived at maturity, or of the ovary combined with the bracts, calyx, or other floral envelopes.
2. The Fruit may be formed by the parts of a single flower, and then it is Simple or monanthous; or by the parts of several flowers united, and then it is called Multiple, collective, anthocarpous, or polyanthous.
3. The parts of a mature ovary are the Pericarp or Integuments, and the Seed with the Embryo.
4. The Pericarp consists of an outer covering called Epicarp or Exocarp, of an inner called Endocarp or, if stony, Putamen, and occasionally of a distinct middle coat called Mesocarp or, if fleshy, Sarcocarp. In some instances, a special covering exists in the form of an aril, which is either funicular or micropylar.
5. Changes take place in the ovary while becoming the fruit, by obliteration of parts, by the growth of cellular tissue, and by foldings and partitions of different kinds. In order to know fully the structure of the ripe fruit, reference must be made to the ovary in its young condition.
6. Fruits, when formed of one carpel, are called monocarpellary; and when of more than one, they are polycarpellary. Sometimes the terms bicarpellary, tricarpellary, tetracarpellary, and pentacarpellary, are used to indicate fruits formed by two, three, four, and five carpels.
7. A monocarpellary fruit, and polycarpellary fruits with distinct and separate carpels, are called Apocarpous. Fruits in which the carpels are united by their ovaries, or by their ovaries and styles, or by their ovaries, styles, and stigmas, are called Syncarpous.
8. The number of carpels in a Syncarpous fruit is indicated usually by the number of partitions in the ovary, or by the number of styles and stigmas.
9. When the partitions (septa) extend to the centre, the number of loculaments will in general point out the number of carpels in a Syncarpous fruit.
10. A Fruit is unilocular, bilocular, trilocular, quadrilocular, quinquelocular, or plurilocular, according as it has one, two, three, four, five, or many separate cavities in its ovary. A unilocular fruit, however, may be composed of several carpels, the partitions between which are parietal only.
11. Fruits are either Dehiscent or Indehiscent. In the former case, they fall to the ground without opening; in the latter, they open to scatter the seeds.
12. Monocarpellary Fruits dehisce usually by their ventral or dorsal suture. Polycarpellary Fruits dehisce in a septicidal, loculicidal, septifragal, circumscissile or opercular, and porous manner. The parts which separate are called valves.
13. Fruits are either Dry or Succulent. In the former, the parts of the pericarp are often confounded together, while in the latter, they are frequently separable.
14. Fruits containing one seed are monospermic, those containing two are dispermic, many, polyspermic.
15. Monospermic dry Fruits are often indehiscent, and are apt to be confounded with seeds, and may be distinguished by the presence of the stigma.
16. When Seeds are contained in an ovary, as is usually the case, the plants are called Angiospermous; when the seeds are not contained in a true ovary with a style or stigma, then the plants are called Gymnospermous.
17. The seed is attached to the placenta by the funiculus. The organic base of the seed is the hilum, while the organic apex is the micropyle.
18. Like ovules, seeds are orthotropous, campylotropous, or anatropous. In the last, the presence of a distinct chalaza and raphe indicates their nature.
19. The Integuments of the seed are called Spermoderm, and consist usually of two parts—the Episperm, Testa, or Exosperm, and the Endopleura or Tegmen. Occasionally, a middle coat or mesosperm is present, which, when fleshy, receives the names of Sarcosperm or Sarcoderm.

20. The Seed contains the embryo either alone, or with a supply of nourishing matter called Perisperm or albumen. In the former case, the seed is exalbuminous, in the latter, albuminous.
21. Seeds usually contain one embryo, and are said to be monembryonous; but instances occur in which several embryos exist in a seed, and it is then said to be polyembryonous.
22. The sac of the Embryo sometimes continues distinct in the seed in the form of a vitellus, and the albumen is either deposited outside the sac (perisperm), or inside the sac (endosperm), or in both situations at once.
23. The Embryo consists of an axis, the lower extremity of which is the radicular portion or radicle; the upper extremity is the cotyledonary portion. From the axil of the cotyledon or cotyledons the first bud, called plumule or gemmule, proceeds.
24. The Radicle or base of the embryo points to the micropyle. In orthotropal seeds the embryo is inverted, in anatropal seeds it is erect.
25. The chalazal end of an anatropal seed corresponds to the cotyledonary extremity of the embryo; the funicular end of an anatropal seed to the radicle of the embryo.
26. The Embryo occupies different positions in the seed, being either in the centre, or at the side or at the base of the albumen. It is also either straight, or curved or twisted in different ways.
27. An embryo with two cotyledons is Dicotyledonous, and is met with in Exogens; an embryo with one cotyledon is Monocotyledonous, and occurs in Endogens; while an embryo without cotyledons is Acotyledonous, and is found in Cryptogams.
28. A Monocotyledonous Embryo is composed of a unifoliar phyton; a Dicotyledonous embryo is composed of a bifoliar phyton; while an Acotyledonous embryo is a cellular leafless phyton.

CHAPTER IV.

NUTRITIVE AND REPRODUCTIVE ORGANS OF FLOWERLESS PLANTS.

I. GENERAL REMARKS ON THESE ORGANS.

414. Although allusion has been cursorily made to these organs in the foregoing pages, still it seems necessary to give a fuller and more connected view of them. As regards elementary tissues, Flowerless or Cryptogamic plants are composed either entirely of cells, as occurs in Sea-weeds and Mushrooms; or of cells and vessels united, as seen in Ferns, Mosses, and their allies. The vascular tissue consists chiefly of pleurenchyma (Fig. 45, p. 23) with closed spirals, annular (Fig. 66, p. 28), and scalariform vessels (Fig. 68, p. 29). In the simplest plants, as Protococcus (Fig. 933), the cell performs all the functions necessary for the nourishment and reproduction of the plant. In the more complicated Flowerless plants, there are some organs specially adapted for nutrition or vegetation, and others for reproduction. Between the Protococcus, a simple cell with thin transparent and colourless walls, and the Tree-fern (Fig. 934) and Pepperwort, with stems and leaves, there is a wide difference. Nevertheless, they are united by intermediate forms. The permanent organization of some Cryptogamics low in the scale is only the temporary condition of higher tribes.

415. In Ferns, Pepperworts, and the higher Cryptogams, there are roots, conspicuous stems, and leaves, for the purposes of nutrition, and certain special organs destined for reproduction. As these tribes produce a foliaceous axis or corm, they are denominated *Cormogens* or *Cormophytes* (Fig. 934), and when their stems are woody, they present the acrogenous structure as described in paragraph 136. In the lower Cryptogamics there are no true roots, nor stems, nor leaves, and their nutritive and reproductive organs are frequently assimilated. These tribes, from having no foliaceous axis, but simply a cellular expansion, have been called *Thallogens* or *Thallophytes* (Fig. 935).

416. In the lowest plants, a few simple cells, either separate or combined, perform the part of nutritive organs. In the case of the Protococcus, the plant of Red and Green snow (Fig. 933), a rounded cell constitutes the whole plant; in Oscillatorias, the cell is elongated; in many Confervas, a congeries of cells is united in a single row; and

in certain Algæ (Fig. 936) and Moulds, the cellular filaments or threads give off branches. The vegetative system of Fungi consists of

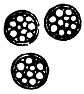


Fig. 933.

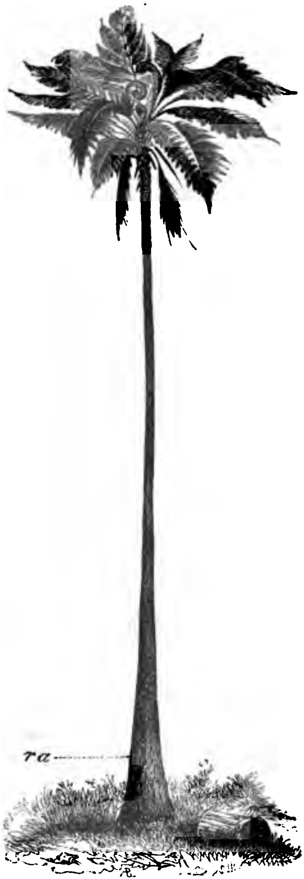
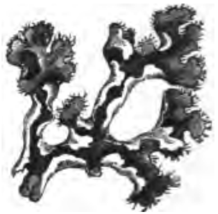


Fig. 934.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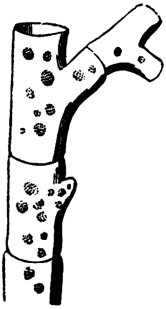
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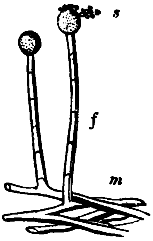


Fig. 937.

Fig. 933. Green-snow plants (*Protococcus viridis*), consisting of single cells, which perform all the functions of nutrition and reproduction. The parent cells contain numerous cellules, which are discharged when the outer general covering gives way. Each of the cellules so separated gives rise to a distinct plant, and they may be considered either as spores or as cellular buds.

Fig. 934. A Tree-fern (*Alsophila Perrottetiana*), with a conspicuous acrogenous stem, bearing a cluster of leaves (fronds) at the apex. The stem is hollow, and bears the scars of fallen leaves on its exterior. At the base of the stem there is a thickening, *ra*, due to the formation of adventitious roots, which descend from the points where the leaves were attached.

Fig. 935. Iceland Moss (*Cetraria islandica*), a species of Lichen, with a flattened cellular expansion (thallus), bearing fructification in the form of apothecia. The plant is thallogenous.

Fig. 936. Branching cellular filament of a Conferva (*Chætophora*), composed of cylindrical cells placed end to end, and containing green matter (endochrome).

Fig. 937. Mould plant (*Mucor*), composed of a mycelium or spawn, *m*, whence arise septate filaments, *f*, ending in a large round cell, *s*, containing spores, which are discharged by the bursting of the bag enclosing them.

colourless filaments (Fig. 937, *m*) called *mycelium*, the cells of which contain no *endochrome* or coloured particles. These filaments are either in the form of continuous canals, or they have partitions, so as to appear in the form of septate tubes. In Lichens and many Sea-weeds, the nutritive organs consist of a series of cells united, so as to produce a flat expansion or *thallus* (Fig. 935). This thallus varies in colour. It is red, for instance, in some Sea-weeds, and green in others. The structure of the thallus is either homogeneous, as in the lower Algæ, or heterogeneous, as in the higher Algæ. In the latter case, there may be distinguished different cellular strata called external or cortical, internal or medullary, and intermediate or subcortical. In Ferns, Pepperworts, Club-mosses, and Mosses, the union of cellular and vascular tissue gives rise to a more complex form of organization, resembling very closely that of Phanerogams. The nutritive organs of Cryptogams produce frequently peculiar buds, *gemmæ* or *innovations*, as they are called, which are capable of being detached from the plant, and of forming new individuals. The integumentary covering of Cryptogams is sometimes only of a cuticular nature without stomata, as in Algæ, while at other times it is epidermal and bears stomata, as in Ferns, Mosses, and Liverworts.

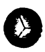


Fig. 938.

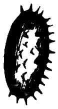
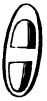


Fig. 939.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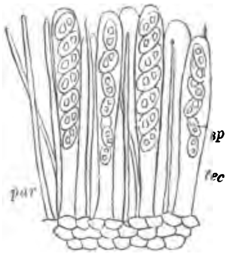

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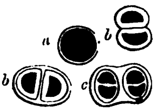

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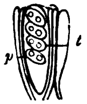


Fig. 943.

417. While the nutritive organs of Cryptogamic plants thus bear

Fig. 938. Round spore of a Fern (*Pteris longifolia*). It has a double covering. The outer layer is marked with three lines.

Fig. 939. Elliptical spore of the Brittle Bladder-fern (*Cystopteris fragilis*). The outer covering is marked with pointed projections.

Fig. 940. Sporidium of a Lichen, containing two cells within a common covering. Some think that these two cells conjugate and give rise to a mass of spores. The sporidium, when complete, often contains numerous small cellules or germinating spores. A sporidium with two cells, such as represented in the figure, is sometimes called a bispore.

Fig. 941. One of the lower Algæ (*Palmella cruenta*), consisting of a cell, *a*, with mucilaginous contents, which divides, first into two, *b b*, and then into four, *c*. Each of the four divisions is capable of propagating the plant when they are discharged from the mother-cell. This is one of the simplest known plants, being composed of a single cell, which performs the functions of nutrition and of reproduction.

Fig. 942. Vertical section of the fructification of a Fungus (*Peziza*). It consists of thecæ or bags, *tec*, each containing eight nucleated cells (Sporidia). Along with the thecæ are filaments called paraphyses, *par*.

Fig. 943. Theca or ascus, *t*, of a Lichen, with nucleated cells (Sporidia) in its interior. Along with it are paraphyses, *p*.

a greater or less resemblance to those of Phanerogams, the case is very different with the reproductive organs. Cryptogams have no flowers and no true seeds; they are propagated by cellular bodies denominated *Spores* (Figs. 938 and 939), which are cells capable of sprouting and forming new plants, and which some have called cellular embryos without cotyledons, or leafless phytons. The plants are consequently Acotyledonous (¶ 406). The origin of these spores is very obscure, but they appear to be formed through the medium of certain cellular organs of a reproductive nature.

418. The term spore should be confined to the ultimate germinating cell of Cryptogamics. It is frequently, however, applied to the cell in which the true spores are formed. Hence spores have been called simple or compound, according as they are formed by one or by several cells. The term *Sporidium* is applied to the compound spore of Lichens. Thus, in Figure 940, there is a sporidium containing two cells, while in Figure 941 there is a mother-cell, which divides first into two and then into four germinating cells. When the cells are numerous they are either placed end to end, so as to be in the form of a septate or partitioned sporidium, or they are accumulated into a mass, called a cellular sporidium. The latter is often the advanced stage of the former, as seen in Lichens. In simple spores, the walls are either simple, as in Botrytis, or double, as in Ferns.

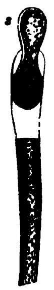


Fig. 944.

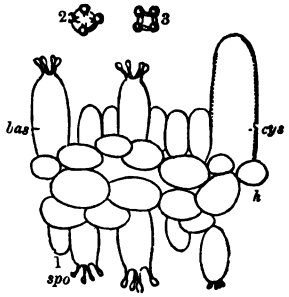


Fig. 945.

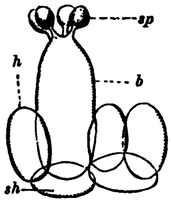


Fig. 946.

419. Spores are developed either in the interior of the cell which

Fig. 944. Clavate cellular filament of an Alga (*Vaucheria ovoidea*). The terminal portion becomes separated from the rest by a partition. In this portion the single spore, *s*, is developed, which is discharged through an opening, as seen in the figure. The spore has cilia, by means of which it moves about for some time in water after being separated from the parent cell. The lower part of the filament contains green endochrome. The spore is of a very dark green colour.

Fig. 945. Portion of the lamella or gill of a Mushroom (*Agaricus campestris*), cut transversely, showing the two lateral surfaces on which the spores are placed. The spores are arranged in fours, *spo*, 1, 2, 3, and supported on cells called basidia, *bas*. The spores being on the outside of a cell are called exospores, and the plant is basidiosporous. There are also peculiar granular bodies contained in sacs called cystidia, *cys*. The cells forming the hymenium and subhymenium are marked *h*.

Fig. 946. Portion of the lamella or gill of the Mushroom (*Agaricus campestris*), cut transversely, showing one of the lateral surfaces. The Hymenium, *h*, has a layer of cells below it called the subhymenium, *sh*; the four spores, *sp*, are on the outside of a cell called basidium, *b*, and the spores are on stalks (sterigmata).

gives origin to them, or on the outside of it. In the former case, they are called *Endospores*, in the latter, *Exospores* or *Gymnospores*. In Protococcus (Fig. 933, p. 312) and in Mucor, the fructification consists of numerous spores in the interior of a mother-sac, more or less spherical. In Palmella (Fig. 941), the mother-cell contains two or four spores. In Pezizas (Fig. 942) and Lichens (Fig. 943), the sporidia (or cells containing spores) are usually four, six, or eight in number. In Vaucheria, only one spore is produced in the mother-cell (Fig. 944, *s*), while in Lavers, Fuci, Liverworts, Mosses, and Ferns, the endochrome or coloured matter filling the mother-cells divides into four parts, each of which becomes a spore, thus resembling the production of pollen-grains in Phanerogams (¶ 306). The large cell, containing one, four, six, eight, or numerous spores or sporidia, receives the name of *Theca* (Fig. 942, *tec*).

420. The exospores or naked spores in the Yeast plant, and in Moulds such as Aspergillus and Penicillium, consist of elongated filaments which are formed by a series of cells placed end to end. When ripe, the cellules separate. In Botrytis and Isaria, a single spore only constitutes the exospore, while in Cantharellus there are two, and in Agarics four (Fig. 945, 2, 3). Leveillé called the mother-cell, on the exterior of which one, two, four, or many spores are formed, a *basidium* (Fig. 945, *bas*). In Agarics, the basidia bearing four spores at their extremity are in general united together so as to form a tissue called *hymenium* (Fig. 946, *h*). In Lichens, Sphærias, and Pezizas, the thecæ containing four, six, or eight spores or sporidia placed one above the other are often separated by filaments called *paraphyses* (Fig. 942, *par*), and the united thecæ and paraphyses constitute the hymenium.

421. The hymenium or the spore-bearing surface is placed on the tissue forming the cortical or medullary layers (strata) of the plant. These strata, sometimes called generically the *excipulum*, may be flat, as in Usnea, and then called *apothecium*, or hollow, as in Peziza, and then called *receptacle;* or they may form a closed cavity with an opening (ostiolum) only at one part, and then they are called a *conceptacle* or *perithecium*. Conceptacles, when united together, are sometimes surrounded by a general covering to which the name of *peridium* has been given. The mass of conceptacles, whether free or united, and enveloped in this peridium, have been sometimes denominated *gleba*. The peridium is sometimes formed of two membranes, as in Geaster, the outer one of which splits so as to allow the inner to appear, and the latter in its turn opens at a fixed point to discharge the spores.

422. In Ferns and Mosses, the hollow cavities containing the spores receive the name of *sporangia* or spore-cases. They are situated either at the extremity of the axis (Fig. 947, *s*) or in the axil of leaves, or on the back of leaves (Figs. 948 and 950). In Mosses, certain cells occupying the centre of the sporangium are sterile, and unite to form a central column denominated *columella*. In Salvinia,

the spores are fixed to a kind of placenta by a cord, and the membrane enclosing them has been called a *sporocarp* (Fig. 951).

423. In some instances, certain minute cells are produced called *sporules.* They are met with in some of the rose-coloured Sea-weeds and in Marchantia (Fig. 949, *g*). They are capable of reproducing the plant, and are looked upon by some authors as forms of buds or

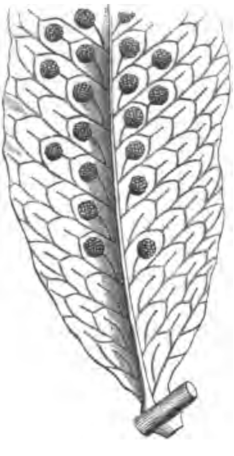


Fig. 948.

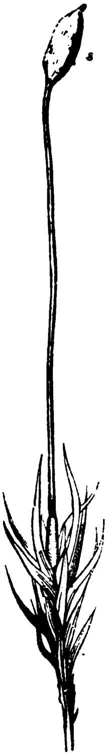


Fig. 947.

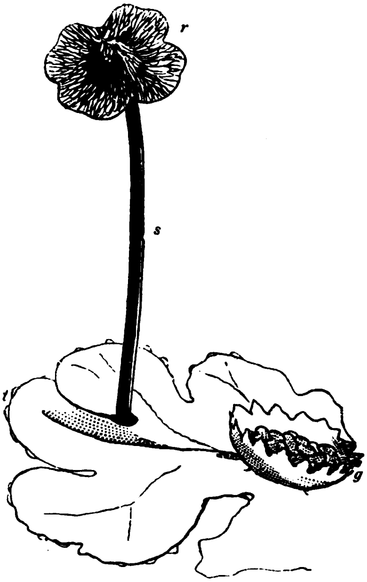


Fig. 949.

Fig. 947. Fruiting stalk of Hair-moss (*Polytrichum*). The leaves are awl-shaped (subulate), and arranged alternately. The seta or stalk rises from leaves called perichætial. The stalk has a sheath at its base; at its apex is the sporangium, *s*, or spore-case, which is an urn-shaped sporiferous (spore-bearing) bag, having a lid or operculum at its summit. This fruit-bearing stalk arose from a cell of the pistillidium after impregnation, and it is considered as an instance of alternation of generations. The fructification, as seen in the figure, is the second generation, and differs totally from the first.

Fig. 948. Frond (fructiferous leaf) of a Fern (*Niphobolus*), showing sori, or round clusters of sporangia at the ends of veins. As these sori are on the back of the frond, the Fern is called dorsiferous.

Fig. 949. Portion of the thallus, *t*, of Liverwort (*Marchantia polymorpha*). From the thallus arises a stalk, *s*, bearing a peltate receptacle, *r*, containing antheridia in its substance. At another part of the thallus is a cup-like body, *g*, containing small rounded cells, called by some sporules, and by others germs, buds, or bulbils. They produce new plants when separated from the parent. They do not seem to be developed by a process of reproduction, and thus they resemble buds; but they differ from the latter in being produced in a special organism.

bulbils. They differ from the latter, however, in being produced in special organisms. They appear to occupy an intermediate position between buds and spores, resembling the former in not being developed by a process of reproduction, and the latter in being contained in special organs.

424. Spores are generally regarded as being produced by the agency of certain organs equivalent to the stamens and pistils of Phanerogams. These organs have been demonstrated more or less completely in all the orders of Cryptogamic plants, and they have

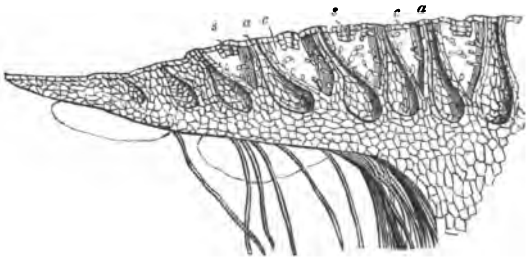


Fig. 952.

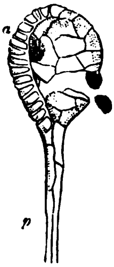


Fig. 950.

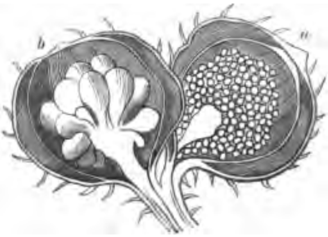


Fig. 951.

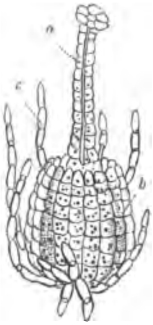


Fig. 953.

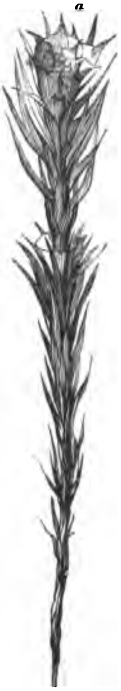


Fig. 954.

Fig. 950. Mature sporangium of the Male Fern (Lastrea Filix-mas). It is supported on a stalk, *p*, some of the cells of which form an elastic ring or annulus, *a*, round the spore-case. The spore-case opens at the side to discharge the spores.

Fig. 951. Sporocarp or involucre of Salvinia, showing large pear-shaped spores in one cavity, *b*, attached to a placenta, and smaller spores (probably antheridia), in another cavity, *a*.

Fig. 952. Vertical section of a portion of the peltate receptacle of Liverwort (*Marchantia*), showing the antheridia, *a a*, or flask-like sacs containing phytozoary cells. Between the antheridia there are air cavities, *c c*, communicating with stomata, *s s*.

Fig. 953. Pistillidium of Liverwort (*Marchantia*), surrounded by its cellular covering, *b*, and by septate filaments called paraphyses, *c*; and surmounted by a style-like calyptra, *a*.

Fig. 954. Plant of Hair-moss (*Polytrichum*), bearing at its summit antheridia, *a*, which are covered by altered leaves. This moss is called diœcious, inasmuch as antheridia and pistillídia are on separate plants.

received the names of *antheridia* (Fig. 952, *a*), and *pistillidia* or *archegonia* (Fig. 953), the former representing the stamens or the male, the latter the pistil or the female. The antheridia were early noticed by Hedwig in the case of Mosses, and their presence has of late years been detected in nearly all the Cryptogamic tribes. In all Cryptogams with distinct stems and leaves, as Ferns, Horsetails, Club-mosses, Pepperworts or Rhizocarps, Mosses, and Liverworts, bodies called antheridia and pistillidia have been demonstrated. In Mosses (Figs. 947 and 954) and in Liverworts (Figs. 949 and 955), they occur on the fully developed plants. In Ferns and Horsetails, they are seen on a cellular structure of a leafy character, called the *pro-embryo* or *pro-thallus* (Fig. 956) developed from the spores. In some Mosses, the antheridia and pistillidia occur on different plants (Figs. 947 and 954), which are hence called diœcious. The union of the two appears to be required for the perfection of the spore or cellular embryo.

425. In antheridia, there have been detected moving filaments to which the name of *phytozoa* or *spermatozoids* has been given (Figs. 957 and 958). These filaments do not germinate. Phytozoa have been detected in Charas, Liverworts, Mosses, Sea-weeds, and Fungi. In the first three, the phytozoa are in the form of small vermiform filaments swollen at one extremity, and having two very long and slender threads at the other (Fig. 959). Each phytozoon is formed in a special cell, is rolled upon itself in a spiral manner (Fig. 958, 2), and escapes either by a pore or by a dissolution of the wall of the cell. In Sea-weeds (Fig. 960), the phytozoa have the threads projecting from either extremity of an obovate body. In the thecæ and sporangia, also, of many Cryptogamics, certain moving spores have been observed, furnished with vibratile threads or cilia (Figs. 961, 962, 963, and 964). These spores have been denominated *zoospores* or *sporozoids*. Their motions seem to be connected with vibratile processes which vary in number, and which proceed from different parts of the spore. In Figure 962 there are two filaments at one end of the spore, in Figure 961 four, and in Figure 963 many; while in Figure 964 the filaments surround the spore completely. These spores move about in fluid until they begin to sprout, at which time the motions cease and the cilia disappear.

426. It would appear from recent researches that many spores, when sprouting, produce organs which resemble the permanent state of other Cryptogams lower in the scale. Thus Mosses, when germinating, exhibit elongated greenish filaments in every respect analogous to Confervæ. Ferns in their infancy resemble completely the adult Liverworts, having a green flat pro-embryo like the thallus of the latter (Fig. 956). The pro-embryo or pro-thallus afterwards gives rise to the proper stem and frond of the Fern. The membranous thallus is a permanent state of the Liverworts, but a transition state of Ferns. The higher Cryptogams would thus appear to pass through

a pro-embryonic or pro-thalloid state, and it is often in this condition that the antheridia and archegonia are seen, which are considered the organs of reproduction. These organs, when existing on the prothallus, do not at once give origin to a germinating spore, but produce a cellular body from which, at a future period, the fructiferous or fruit-bearing frond arises. There seems to be an alternation of generation in these instances. In the first stage, a thalloid expansion

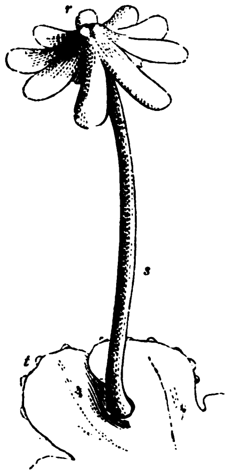


Fig. 955.

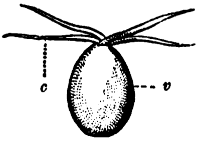
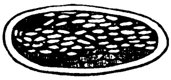


Fig. 961.



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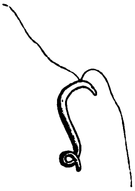

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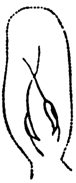

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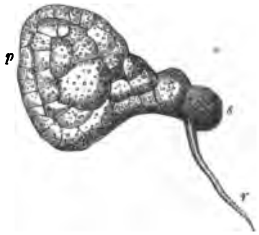


Fig. 956.

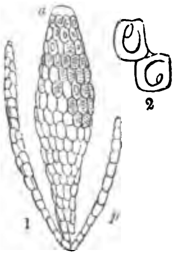


Fig. 958.

Fig. 955. Part of the thallus, *t*, of Liverwort (*Marchantia*), bearing a stalk, *s*, which ends in a divided receptacle, *r*, on the under surface of which sacs containing spores and elaters are produced. This is considered a female plant, bearing pistillidia only, while, in Figure 949, a male plant is represented. Hence, the plant is said to be diœcious.

Fig. 956. Spore, *s*, of a Fern (*Pteris longifolia*) sprouting, giving off a root-like process, *r*, and a flat cellular expansion, *p*, called the pro-thallus or pro-embryo. On this expansion antheridia and pistillidia are said to occur. A cell of the latter is afterwards developed into a frond bearing sporangia and spores. It is said to be an instance of alternation of generations. The pistillidian body is sometimes called the ovule, and the developed cell is called the sac of the embryo.

Fig. 957. Antheridium of a Sea-weed (*Fucus serratus*), containing numerous phytozoa or spermatozoids in its cellules.

Fig. 958. Antheridium, 1, *a*, of the Hair-moss (*Polytrichum*), consisting of cellules, 2, containing phytozoa coiled up in their interior. The phytozoa have a thickened extremity, whence proceeds a tapering tail-like process. Along with the antheridium are two septate filaments or paraphyses, *p*, which are probably abortive antheridia.

Fig. 959. Phytozoon or spermatozoid, from the antheridium of Chara. It has two long vibratile processes at one extremity, and to these its movements are referred.

Fig. 960. Antheridium of a Sea-weed (*Fucus serratus*), still containing two of the phytozoa, which consist of a swollen portion, with filaments proceeding from either extremity. The phytozoa exhibit movements.

Fig. 961. Moving spore (Zoospore or Sporozoid) of an Alga (*Chætophora*), consisting of a cell, *v*, with four cilia or vibratile processes, *c*, at one extremity.

is what the spore produces. This is the first phase of existence. The pro-thallus then gives rise to the next stage, in which sporangia are produced with spores in their interior; this constitutes the second phase of existence. These phenomena have been particularly observed in Ferns by Suminski, Wigand, and De Mercklin.*

427. In reviewing what has been recently done in this interesting department of Cryptogamic botany, Henfrey gives the following statements:—The antheridia of Mosses (Fig. 958), Liverworts (Fig. 952, *a*), Ferns, and Horsetails, agree with what authors called the *small spores* in Quillwort, Pillwort, and Salvinia, in producing cellules containing phytozoa or spiral moving filaments. These antheridia constitute one of the sexual organs. The pistillidia of Mosses and Liverworts (Fig. 953) agree with the so-called *ovules* or peculiar spores of Ferns, Horsetails, Club-mosses (Fig. 965), Quillworts, and Rhizocarps (Fig. 966), in general structure and in the presence of a large cell, called the embryo-sac by some, from which the new form of structure originates. These pistillidia constitute the second sexual organ.

428. In Mosses and Liverworts the antheridia and pistillidia may be considered equivalent to the stamens and pistils, the sporangium being the fruit; or we may, with Hofmeister, regard it as an alternation of generations—the pistillidium being considered an ovule producing a new individual (viz., the sporangium) of a totally different character from that developed from the spore (viz., the leafy moss-plant, in the usual acceptation of the term). In Ferns and Horsetails, the spores produce a frondose structure of a definite form (pro-embryo or pro-thallus), upon which are developed antheridia and pistillidia, or ovules of some authors. This seems to be one generation completed; and the new development from the so-called ovule appears as a totally distinct form, producing stem and leaves, which have

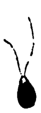
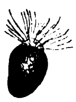


Fig. 962.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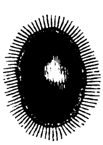
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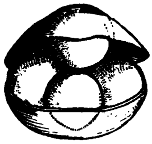
Fig. 965.

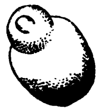
Fig. 966.

Fig. 962. Zoospore of an Alga (*Conferva glomerata*), with two moving cilia at one end.

Fig. 963. Zoospore of an Alga, with a tuft of cilia at one end.

Fig. 964. Zoospore of an Alga (*Vaucheria*) surrounded by moving cilia.

Fig. 965. Larger spores of Club-moss (*Lycopodium*), inclosed in an involucre. It is sometimes called an oophoridium in consequence of containing germinating bodies (ovules). It is considered as representing the female organ. The involucre opens transversely to discharge the spores.

Fig. 966. Ovule or spore-case of Pepperwort (*Marsilea*), containing a single germinating spore. There is a little projection or mammilla at the summit, whence the roots and leaves proceed during germination.

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* Leszczyc-Suminski Zur Entwickelungs-geschichte der Farrnkräuter, Berlin, 1848; and also Ann. des Sc. Nat. 3d Ser. Bot. xi. 114. Wigand, Zur Entwickelungs-geschichte der Farrnkräuter, Botan. Zeitung, 1849; also Ann. des Sc. Nat. 3d Ser. Bot. xi. 126. See also Mercklin, Beobachtungen an dem Prothallium der Farrnkräuter, 1850.

a distinct individual form and structure, and produce the spores after a long period upon temporary parts of this structure (*i.e.*, on the leaves), and by no means cease to exist when these are matured. This is then a real alternation of generations. Hofmeister compares the whole permanent plant of the Fern or Horse-tail to the sporangium of a Moss or Liverwort. The pistillidia of Mosses and Liverworts are considered by him the analogues of the so-called ovules of higher Cryptogams, while the sporangium is considered as the analogue of the perfect plant of Ferns, and the leafy stem as the analogue of the pro-embryo of Ferns.*

II. NUTRITIVE AND REPRODUCTIVE ORGANS OF DIFFERENT ORDERS OF CRYPTOGAMIC PLANTS.

1. Organs of Ferns and their Allies.

429. *Ferns* or *Filices* are composed of cellular and vascular tissue. They have roots, leaves, an acrogenous stem, and an acotyledonous embryo. The stem or *caudex* either rises conspicuously into the air, as in the case of Tree-ferns with their elegant foliage (Fig. 967), or it appears as a rhizome running along the surface of the earth or under ground, as seen in the native Ferns of Britain (Figs. 968 and 969). The stem contains vascular bundles consisting of woody, dotted, annular, closed spiral, and scalariform vessels (Fig. 970). The last are characteristic of Fern structure. These vascular bundles are arranged in a peculiar manner, as shown in Figures 971 and 972. In the former figure, which represents the section of a Tree-fern stem, the woody tissue or pleurenchyma, *f*, is of a dark colour, and surrounds the other vessels, *v*, which are of a pale colour; the parenchyma is distributed partly in the centre, *m*, and partly at the circumference, *p*, and the bases of the leaves, *e*, form an external covering. The appearance presented by the vascular bundles, *f*, of the Male Fern is shown in Figure 972. In the case of the common Brake (Pteris aquilina), the arrangement of the vascular bundles, when the stem is cut, gives an appearance resembling a double eagle, and hence the specific name.

430. The trunk of Tree-ferns is hollow when fully formed, gene-

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* For fuller details on the subject, see Henfrey's Report on Cryptogamic Reproduction, in the Transactions of the British Association for 1851; and for a complete Treatise on the organs of Cryptogamic plants consult Payer, Botanique Cryptogamique, Paris, 1850. See also Mohl, einige Bemerkungen uber die Entwickelung und den Bau der Sporen der Cryptogamischen Gewachse; Hofmeister, Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen, Leipzig, 1851.

rally simple, sometimes dichotomous, having on the outside leaf-scars which display the markings of the vascular bundles (Fig. 973 and Fig. 204, p. 93). The external surface of the stem, especially at the lower part, is often covered by adventitious or abnormal roots (Fig. 934, *ra*, p. 312). The stem is formed by the union of the bases of the leaves, which carry up the growing point with them, and in this way the stem increases by additions to its summit, or is acrogenous (¶ 136). In consequence of this mode of growth there is little increase in diameter.

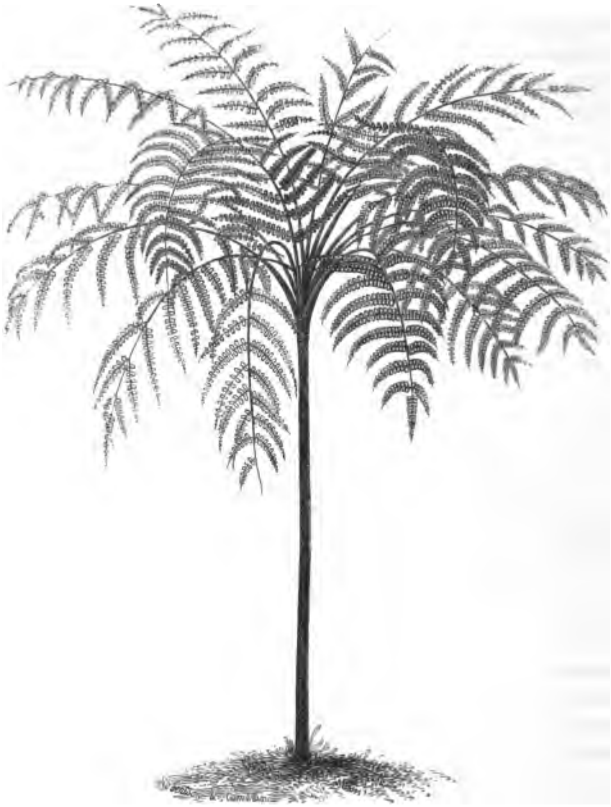

Fig. 967.

431. The leaves which are called *fronds* are produced at the summit of the stem (Fig. 967), and they form a very graceful crown or coma. In the young state, they are rolled up in a circinate

Fig. 967. Tree-fern with its slender cylindrical trunk, and crown of elegant drooping fronds, on which the fructification is produced. This stem is acrogenous, increasing by additions to its summit.

manner, so as to resemble a crosier (Figs. 974 and 968, *f*). They consist of veins and parenchyma, the former being usually of equal thickness throughout, and divided in a forked (furcate) or reticulated manner. The epidermis has stomata, but they are not very numerous. The fronds bear the fructification. In some instances, they produce bulbils or gemmæ, which, when separated from the plant, take root and give rise to new individuals; such Ferns are called *bulbiferous* or *gemmiparous*.

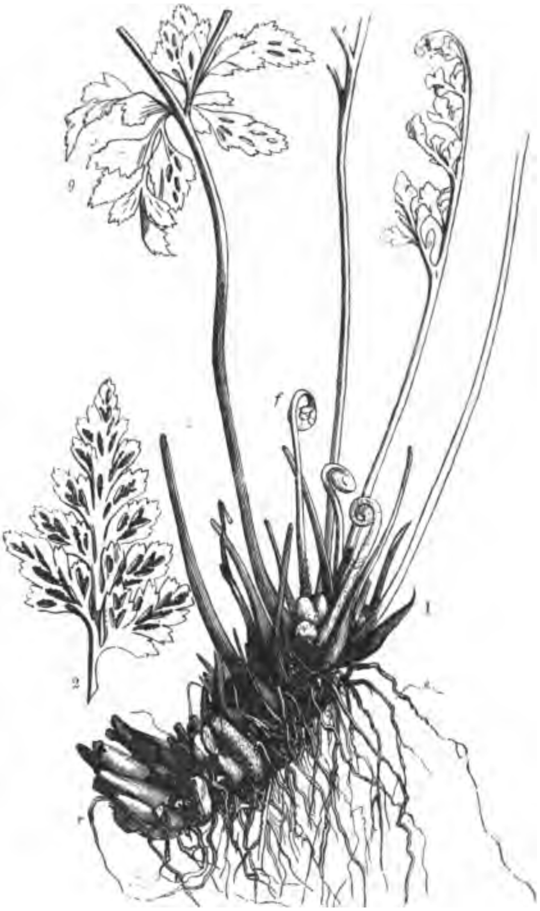

Fig. 968.

Fig. 968. A species of Spleenwort (*Asplenium*). 1, Shows the rhizome, *r*, covered with the bases of the leaves (fronds), and giving off roots; some fronds in bud, *f*, rolled up in a circinate manner, others expanded, *g*, bearing the fructification 2 a portion of a frond separated to show the linear sori or clusters of sporangia.

432. The Venation of Ferns supplies important characters in classification, as has been particularly shown by Mr. John Smith of Kew. The veins, according to him, are either produced equally on both sides of a midrib, or they radiate from near the base, the midrib being evanescent (Fig. 975). Sometimes the primary veins proceed-

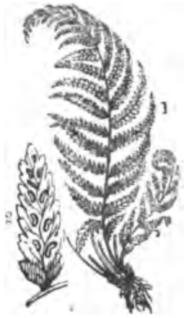

Fig. 969.

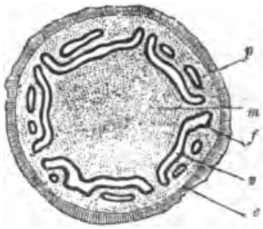

Fig. 971.

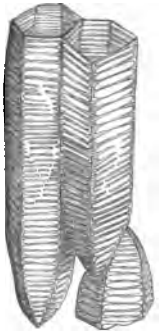

Fig. 970.

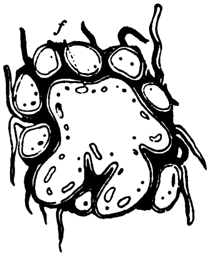

Fig. 972.

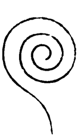

Fig. 974.

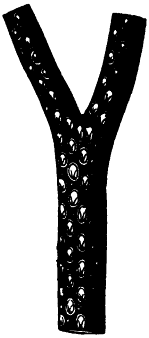

Fig. 973.

Fig. 969. Short-fruited Spleenwort or Lady-fern (*Athyrium Filix-fœmina*). 1, The entire fern with its short rhizome, and its delicate fronds, which, in the young state, are rolled up in a circinate manner; 2, one of the pinnæ, with its pinnules, bearing the oblong slightly-curved sori (clusters of sporangia) on their back. The fern is dorsiferous.

Fig. 970. Scalariform vessels taken from a Tree-fern. They have a prismatic form, and are marked by bars like the steps of a ladder.

Fig. 971. Transverse section of the stem of a Tree-fern (*Cyathea*), showing the arrangement of the cellular tissue and vascular bundles. The cellular tissue of the centre, *m*; that of the circumference, *p*; vascular bundles, *f v*, consisting of dark-coloured woody fibres, *f*, and paler vessels, *v*, chiefly scalariform and closed spiral; the outer cortical portion formed by the bases of the leaves, *e*.

Fig. 972. Transverse section of the Rhizome of the Blunt Shield-fern, often called the male Shield-fern (*Lastrea Filix-mas*), showing the bundles of vascular tissue, *f*, scattered among the parenchyma, and the bases of the leaves which form the stem.

Fig. 973. Bifurcating (forked or dichotomous) trunk (caudex) of a Tree-fern (*Alsophila Perrottetiana*), showing the scars (cicatrices) left by the fallen fronds. These scars exhibit the arrangement of the vascular bundles. The whole stem divides into two equal portions.

Fig. 974. Diagram to illustrate the circinate vernation of the fronds of Ferns. The entire fronds and the pinnæ are rolled up from apex to base like a crosier.

ing from the midrib are simple, at other times forked, the bifurcating branches running nearly parallel (Fig. 976). Sometimes the veins coming from the midrib give off in their turn secondary veins, either simple or forked (Fig. 977). In these bipinnate forms of venation, the secondary veins occasionally unite at their apices, so as to form a sort of intermediate vein more or less complete, and parallel to the primary ones (Figs. 978 and 979). The secondary and tertiary veins sometimes anastomose, so as to form an angular net-work or reticulation (Fig. 980). The veins coming off from the midrib in Figure

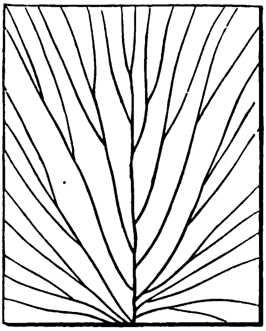

Fig. 975.

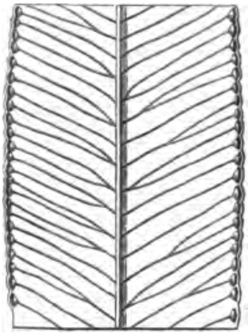

Fig. 976.

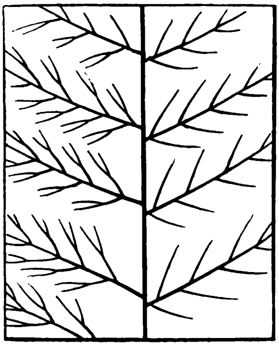

Fig. 977.

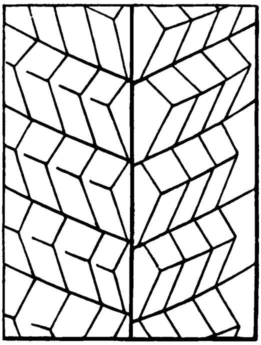

Fig. 978.

Fig. 975. Venation of Ferns, in which the primary veins come off from the midrib, near its base, and the midrib itself becomes evanescent. The veins divide in a forked manner, and hence the venation is called furcate or bifurcate.

Fig. 976. Venation of Ferns, in which the primary veins come off from the midrib throughout. Some of the veins are simple, others are forked. They end in fructification in the margin of the frond.

Fig. 977. Venation of Ferns, in which the primary veins come off alternately from the midrib, and in their turn give off simple or forked secondary veins in an alternate manner.

Fig. 978. Venation of Ferns, in which the midrib gives off alternate primary veins, and these in their turn give rise to secondary veins, the extremities of which unite midway between the primary veins, so as to form an intermediate vein, either continuous or interrupted.

981 unite in a peculiar way, so as to form a sort of angular arch from various parts of which anastomosing veinlets proceed, giving rise to reticulated venation. In Figure 982, the primary veins give off secondary ones, some of which (at the base) are free and simple, while others unite with the veins above and below, and form a sort of arch from which other interrupted veins parallel to the primary veins proceed.*

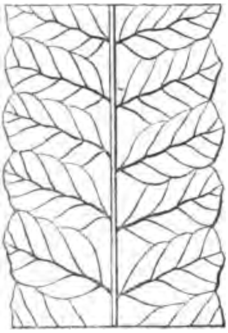
Fig. 979.

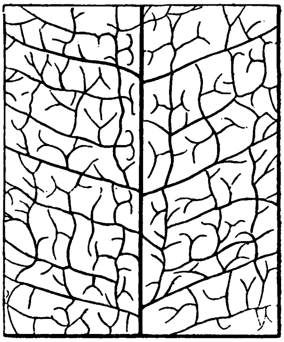
Fig. 980.

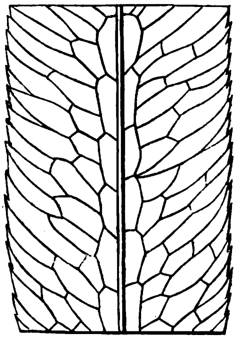
Fig. 981.

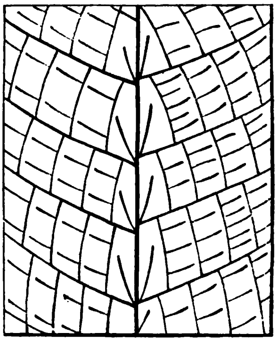
Fig. 982.

Fig. 979. Venation of Ferns, in which the midrib gives origin to alternate primary veins, which in their turn give off secondary veins. The secondary veins from contiguous primary veins unite in a common intermediate vein, which does not extend to the midrib.

Fig. 980. Venation of Ferns, in which the midrib gives off primary veins, which in their turn give origin to secondary veins, and then tertiary veins, so as to form a sort of net-work or reticulation.

Fig. 981. Venation of Ferns, in which the midrib gives rise to short primary veins, which divide into secondary veins, so as to form an anastomosis or net-work of vessels. The veins end in a serrated manner.

Fig. 982. Venation of Ferns, in which the midrib gives off alternate primary veins, which give origin to secondary veins, some of which at the base remain simple, while others subdivide and unite to form a kind of rectangular net-work.

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* For further remarks on the venation of Ferns, see Smith on the arrangement and definition of the genera of Ferns, in Hooker's Journal of Botany, iv. 38.

433. The fructification in its fully developed state appears as *sporangia*,* situated on the veins on the back, or on the margins of the leaves (Fig. 948, p. 316, and Figs. 968 and 969, 2), containing spores. The spore-cases are arranged in clusters (sori) of a round (Fig. 983) or elongated form (Fig. 968, 2), and they are either naked or covered by a layer of the epidermis, which forms an involucre or *indusium* (Figs. 983 and 984). This indusium presents various forms, and is pushed off during growth in different ways, according to its mode of attachment to the leaf. In Figure 983, it is attached by the middle; in Figure 984, by the sinus or termination of the fissure. The clusters of sporangia are sometimes confluent, and form a continuous line bursting through the epidermis. The edges of the fronds are sometimes folded over the sori. It sometimes happens that the sporangia, in place of being in clusters on the back of the frond, as in the *dorsiferous* fructification, appear in the form of a simple or branched spike. In such cases the midrib and veins of the frond constitute the rachis and branches, and the spore-cases and spores are developed at the expense of the parenchyma of the leaf. Thus, in the Royal Fern (Fig. 985), the frond, *f*, is seen presenting the usual foliaceous or leaf-like appearance, and the fructification, *s*, is in the form of sessile or unstalked sporangia, arranged on a fructiferous branching rachis (Fig. 986), and opening by a vertical fissure at the apex. It sometimes

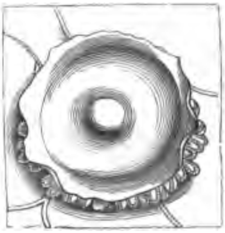

Fig. 983.

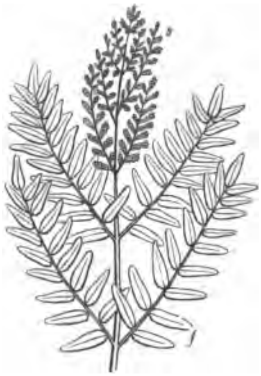

Fig. 985.

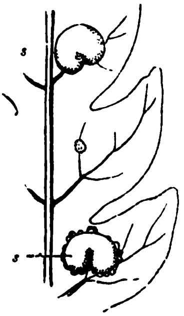

Fig. 984.

Fig. 983. Sorus or cluster of Sporangia of a Fern (*Aspidium trifoliatum*). The Sporangia are covered by an indusium or involucre, derived from the epidermis of the frond. The involucre is round (orbicular), and attached by its centre in an umbilical manner. The annulate sporangia are seen at the lower edge of the involucre.

Fig. 984. Portion of the frond of the male Shield-fern (*Lastrea Filix-mas*), showing two sori, *s s*, or clusters of sporangia covered with a reniform involucre or indusium attached by the sinus.

Fig. 985. Frond of the Royal Fern (*Osmunda regalis*), bearing divided pinnæ, *f*. The frond is bipinnate. At the extremity of the frond the pinnæ are altered so as to bear fructification, consisting of sporangia, arranged in a spike-like manner on a number of short axes. The pinnules, in place of bearing parenchyma, are changed into spore-bearing cells. The morphological changes are often easily traced in specimens in which the pinnæ are partly parenchymatous, and partly sporangiferous.

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* The terms theca and capsule are used by many authors as synonymous with sporangium. Some restrict the term sporangium to the mother-cells in which the spores are developed.

happens that a pinna of Osmunda is partly parenchymatous and partly sporangiferous. A spiked arrangement of sporangia is seen in Moonwort and Adders-tongue. In Hymenophyllum and allied genera, the stalked sporangia are covered by a cup-like process or involucre formed by the frond.

434. The sporangia commence as cellular buds from the parenchyma. Some of the cells constitute the stalk when present (Figs. 987, *p*, and 950, p. 317), others form the sporangium, *s*, in the interior of which spores are formed. It frequently happens that the cells outside the sporangium form an *annulus* or ring (Fig. 987), which is either vertical, and attached by its base, as in Polypody, or horizontal and free, as in Hymenophyllum. The cells composing the ring have walls which vary in thickness on the inner and outer side, and by their unequal contraction finally rupture the delicate sporangium, so as to allow the spores to escape. The ring is very obscure and imperfect in some Ferns, as Osmunda, and it is awanting in Moonwort and Adders-tongue, and in many other Ferns. Hence, some Ferns are called *annulate* (having a ring), others *exannulate* (not having a ring).

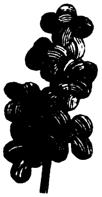
Fig. 986.

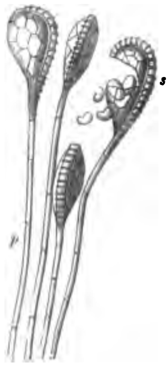

Fig. 987.

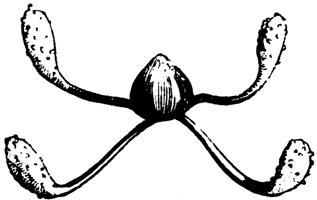
Fig. 991.

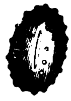
Fig. 988

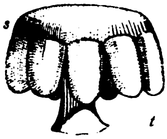

Fig. 989.

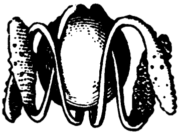
Fig. 990.

Fig. 986. Cluster of sporangia of the Royal Fern (*Osmunda regalis*). The sub-globose sporangia are clustered on the margin of an altered pinna; they have an obscure ring or annulus, are striated, and open by two regular valves.

Fig. 987. Sporangia of a Fern (*Marginaria verrucosa*). They are supported on septate cellular stalks (pedicels), *p*, a continuation of which, in the form of an elastic cellular ring, surrounds the spore-case, *s*. The fern is called annulate, or ringed, on this account. The sporangium, *s*, opens on one side, so as to scatter the spores, and the elasticity of the ring aids in the rupture.

Fig. 988. Spore of a Fern (*Polypodium aureum*), having two cellular coverings, the outer of which is marked by dots, and a linear depression.

Fig. 989. Polygonal scale, *s*, of a species of Horse-tail (*Equisetum*), bearing membranous sacs, *t*, which open on their inner surface to discharge spores.

Fig. 990. Spore of a Horse-tail (*Equisetum*), surrounded by two filaments with club-shaped extremities. The filaments in this state are coiled round the spore.

Fig. 991. Spore of the Horse-tail, with the hygrometric filaments expanded, showing the two club-shaped extremities of each of them. This is their appearance when dry. When moistened or breathed upon they coil round the spore, as in Figure 990. They are interesting objects under the microscope, exhibiting movements according to their state of dryness or moisture.

435. The spores (Fig. 938, p. 313) are covered by a double membrane, and the outer layer is marked with points, as shown in Figures 939, p. 313, and Fig. 988. These spores germinate, and give rise to a peculiar parenchymatous expansion, called the *pro-thallus* or *pro-embryo* (Fig. 956, p. 319), on which peculiar reproductive cells have been discovered by Suminski. Some of these cells contain moving spiral filaments (phytozoa), and are looked upon as antheridia; others of a larger size and oval form contain a mother-cell or embryo-sac, which, after im-

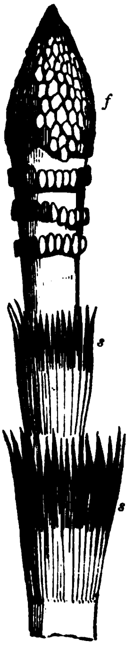

Fig. 992.

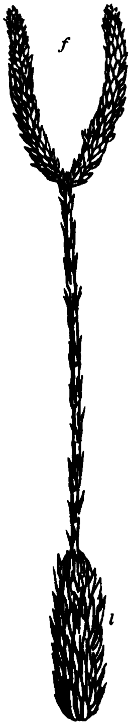

Fig. 993.

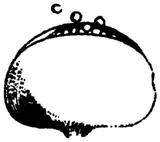

Fig. 995.

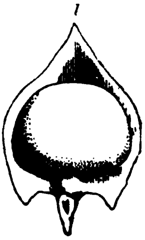

Fig. 994.

Fig. 992. Fructification of a species of Horse-tail (*Equisetum Telmateia*). The stalk is surrounded by a series of membranous sheaths, *s s*, which are fringed by numerous sharp processes or teeth. The fructification, *f*, is at the extremity of the frond, in the form of a pyramidal mass of polygonal scales, bearing spores on their under surface. The fructification in some species is on the same branch with the leaves, while in others, as in the figure, it is on a separate branch.

Fig. 993. Fructification of a Club-moss (*Lycopodium clavatum*). The branch is covered with minute pointed leaves, *l*; from it proceeds a stalk bearing at its extremity two spikes, *f*, consisting of modified leaves, with fructification.

Fig. 994. Fructification of Club-moss (*Lycopodium*), situated in the axil of a leaf, *l*. It consists of a case containing minute cellular bodies, which are discharged in the form of powder.

Fig. 995. One of the cases separated from the axil of the Club-moss leaf, opening by two valves, and discharging the minute Lycopode powder.

pregnation, is supposed to produce the frond bearing sporangia. These stages of growth have already been noticed (¶ 425) as instances of alternation of generations. These views have been adopted by many able physiologists of the present day.*

436. *Horse-tails, or Equisetaceæ.*—The plants of this Cryptogamic order exhibit cells, vessels, epidermis, and stomata. The epidermis is siliceous and striated; the stomata have been shown in some of the species of Equisetum to consist of four cells, two of which are pectinate, presenting on their inner surface numerous projecting processes like the teeth of a comb. They occur in a longitudinal series, and are well seen in Equisetum hyemale, or Dutch Rushes, after the action of nitric acid. The plants have roots, rhizomes, or under-ground stems, and aerial branches, but no true leaves. The rhizomes sometimes extend to the depth of many feet. The stalks sent up from the rhizomes, are hollow and jointed, the articulations being separable, and surrounded by toothed sheaths (Fig. 992, *s*). In the outer cylindrical portion of the stalks there are longitudinal tubes or fistulæ, which alternate with furrows on the exterior. The primary branches arising from the rhizome are sometimes simple, at other times branched—the branches being often verticillate.

437. The fructification in its advanced state consists of spore-cases enclosing spores, attached to the under surface of shield-like hexagonal scales, and collected into a common pyramidal head (Fig. 992, *f*). In Figure 989 is shown one of the stalked scales bearing spore-cases, which split longitudinally on their inner surface. The scale, *s*, has some resemblance to the bracts in the Cypress cones, and it bears on its under surface a circular row of membranous sacs elongated like teeth, *t*. The sacs open towards the centre of the scale, or that part to which the stalk is attached. Within these sacs there are mother-cells which produce each a single spore. This spore is provided with two elastic spiral appendages, which at first completely cover the wall of the mother-cell and enclose the spore (Fig. 990), but finally spread out so as to burst the walls of the sac (Fig. 991). The elastic club-shaped (clavate) filaments remain attached to the spore, and display hygrometric properties, coiling up when moisture is applied,

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* Some who consider the organs of reproduction as existing on the pro-thallus, look upon the cellular body as composed of a series of true spores, only one of which (the central one) comes to perfection. This cell or embryo-sac is not detached from the pro-thallus, but germinates while attached to it, and gives rise to the frond, bearing certain leafy organs called sporangia, with a number of *buds* (the so-called spores) free in their interior. These buds are, according to them, mere extensions of the plant, not produced by impregnation; and, when separated from the frond, they germinate and form a pro-thallus bearing the true reproductive organs. What are usually called spores are by these botanists considered as equivalent to the gonidia or green germs of Lichens. These views, however, have not been adopted generally. For further remarks on the structure of Ferns, see Thurct, sur les Anthéridies des Fougères, in Ann. des. Sc. Nat. 3d ser. Bot. xi. 5. Nees Von Esenbeck ueber die Entwickelung der Farrnkräuter, Isis, 1829. Henderson on the germination of Ferns, Mag. of Zoology and Botany, i. 333. Meyer, ueber die Bedeutung der Organe der Farrnkräuter, Isis, 1829. Link, einige Bemerkungen uber den innern Bau der holzigen Farrnkräuter, Linnæa, 1820. Mohl de structura Caudicis Filicum in Mart. Plant. Crypt. Brazil; besides the Treatises of Suminski, Mercklin, and Wigand already referred to.

and spreading out when dry. If put in the field of a microscope of low power and breathed upon, the movements of coiling and uncoiling are well seen. The spiral fibres or *elaters*, by their elasticity, seem to aid in scattering the spores, and in placing them in circumstances favourable for growth.

438. The spore, when sprouting, produces a pro-embryo or prothallus, which at first appears as a green lobed leaf supported on a stalk, which serves as a root. The lobes of the pro-embryo extend and subdivide until a number of cellular septate tubes are produced, containing green matter. In this pro-embryonic state the Horse-tails resemble Confervæ. It is in this state that bodies resembling the antheridia of Ferns have been detected, as well as peculiar cells, which have been regarded as equivalent to the archegonium or the so-called ovule of the higher Cryptogamics. This latter body gives origin to the aerial stem of the plant which bears the fructification. There would appear to be, in this instance also, an alternation of generations similar to what Suminski has observed in Ferns. The branches which are sent up by the Horse-tail are sometimes barren, producing verticillate leaves only, without any spore-cases or spores. Mohl has observed the development of the spore-case of Equisetum. It appears first as a homogeneous cellular body, in the centre of which are gradually produced greenish granules, surrounded by a special membrane. The green matter is divided into four parts, or mother-cells, each containing a single spore.*

439. *Club-mosses or Lycopodiaceæ.*—These plants have creeping stems or corms, which produce leafy branches, having some resemblance in general appearance to Mosses. Structurally they consist of cells and vessels, the latter occurring in the form of woody and annular vessels, which occupy the axis or central part of the stems. Roots are given off from the primary stem, as well as from different parts of the branches. The leaves are small and sessile, imbricated (Fig. 993, *l*), or verticillate, and on their epidermis stomata exist in small quantity. The plants are interesting, as being allied apparently to fossil plants, such as Lepidodendrons (Fig. 309, p. 132).

440. The fully developed fructification occurs in the axil of leaves (Fig. 994), which are often collected together in the form of a spike (Fig. 993, *f*). The fructification is of two kinds, one being kidney-shaped, two valved cases (Fig. 995), which originate in cellular mammillæ, and ultimately appear as sacs containing cells, with four spore-like bodies in each. These are discharged in the form of yellow dust, known as Lycopode powder, and used, from its inflammable nature, in place of sulphur. Some consider these organs as antheridia containing a matter resembling pollen. The powdery substance has not been seen to germinate. The other kind of fructification con-

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* See Mirbel, sur les Equisetum, Bulletin de la Soc. Philomathique. Agardh, Germination des Equisetum, in Memoires du Museum. Vaucher, Monographie des Presles, in Mem. de la Soc. D'Hist. Nat. de Geneve. Milde on the germination of Equiseta, in Linnæa for October 1851.

sists of a roundish and somewhat four-sided body, called by Müller *oophoridium*, containing four large spores in its interior, and opening by two valves (Fig. 965, p. 320). These large spores, called *ovules* by some, germinate and reproduce the plant.

441. While the first mentioned organ (Fig. 995) is considered by some as an antheridium containing grains like those of pollen, the latter (Fig. 965, p. 320) is looked upon as the pistillidium with ovules. These ovules, it is supposed, produce in their interior a pro-thallus or pro-embryo of small size, from a large cell of which the proper fructifying

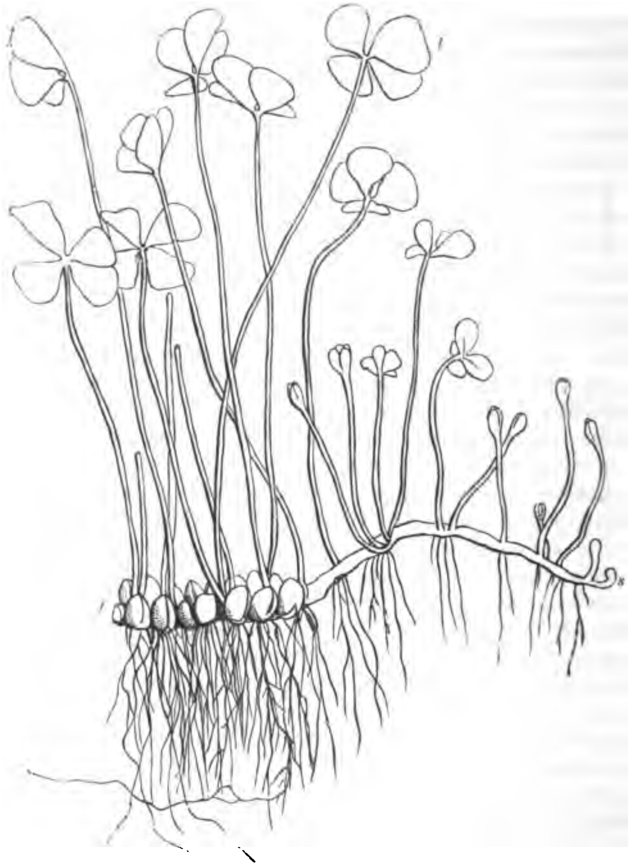

Fig. 996.

Fig. 996. Species of Pepperwort (*Marsilea Fabri*), with its creeping stem, *s*, bearing quadrifoliate stalked leaves, *l*, on one side, and roots on the other. The fructification, *f*, is at the base of the leaves, consisting of sporocarps, which open to allow of the escape of a peculiar receptacle seen in Figure 997.

stem is developed. In Quillwort, the two kinds of fructification are imbedded in the substance of the base of the leaf.*

442. *Pepperworts*, *Marsileaceæ*, or *Rhizocarpæ.*—These plants have creeping stems with leaves, which are divided into three or more cuneate portions, and have a circinate vernation. The leaves have stomata and veins. The stem increases by its extremity. It contains a central vascular bundle consisting of woody and scalariform vessels surrounded by parenchyma. One of the plants called Marsilea is represented in Figure 996, in which the rhizome bears roots on one side and long-stalked leaves on the other, the laminæ of the leaves, *l*, being divided into four parts. The fructification, *f*, is produced at the base of the leaf-stalks. It consists of *sporocarps* or ovoid sacs enclosing organs of reproduction.

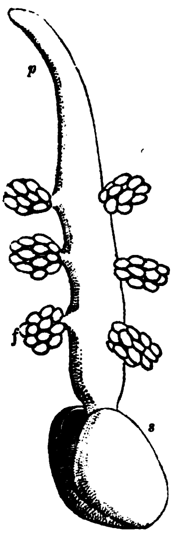

Fig. 997.

443. The sporocarp or, as some call it, involucre, is globular, and is borne on a jointed stalk; the terminal joint (receptacle of some) produces branching and anastomosing fibres which at first give the appearance of membranous partitions, and bear on their ultimate divisions horizontal spike-like masses, at first enveloped in a membrane, and composed of antheridia, and of sporangia or, as some call them, ovules. The latter are large and are placed at the upper part of a gelatinous kind of placenta, while the former are at the lower part. In each spore-case, there is a single spore which germinates by sending out roots and leaves at a little projecting point at the summit. The leaves, at first, are filiform, and then two and four lobed.†

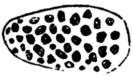
Fig. 998.

444. In Figure 997 is represented the two-valved sporocarp, *s*, of Marsilea open, and giving out a cellular cord (called by some the midrib of the modified leaf forming the involucre), which at first was curved in a ring-like manner so as to unite the valves, and which finally is detached at one end, *p*, bearing the reproductive spike-like

Fig. 997. Fructification of a species of Pepperwort (*Marsilea Fabri*). The sporocarp, *s*, opens to give out a peculiar cellular cord or peduncle, *p*, which at first was curved in a ring-like manner. This cord bears spike-like fructification, *f*, consisting of antheridia and pistillidia enclosed in sacs, and attached to a common axis or placenta.

Fig. 998. Antheridium of a Pepperwort (*Marsilea Fabri*), an obovate sac, containing minute cells with phytozoa.

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* For further remarks on the structure of the Club-mosses, see Müller's paper on the Development of Lycopodium in Botanische Zeitung for 1846, and in Annals of Natural History, xix. 27. Brongniart, Hist. des Vegetaux Fossiles. Delile, Examination de la Vegetation de l'Isoetes setacea. Mohl on Isoetes in Linnæa, xiv. 181.

† See Fabre and Dunal on Marsilea, in Ann. des Sciences Nat. 2 ser. vii. 227; ix. 115; xii. 255. Nägeli, sur la propagation des Rhizocarpées Ann. des Sc. Nat. 3 ser. ix. Valentin on Pilularia, Linnæan Transactions, xviii. 483. Savi, sulla Salvinia natans, 1820. Griffith on Salvinia and Azolla, Calcutta Journal, v.

masses, *f*, on its surface—these masses consisting of antheridia and pistillidia inclosed at first in sacs, and attached to mucilaginous placentas. In Figure 966, page 320, is shown the ovule or sporangium with a sort of projecting hood and a mammilla, whence roots and leaves proceed during sprouting; while in Figure 998 is seen the pyriform antheridium with the grains like pollen in its interior. Some call these grains *small spores* in contra-distinction to the large germinating spores.

445. In Pillwort, the reproductive bodies are in small rounded sacs at the base of the narrow leaves. These sacs are divided internally into four, and they dehisce by four valves. Certain gelatinous processes on the inner side of the walls of the sac bear two kinds of organs, one containing granular matter like pollen, and the other germinating bodies. These apparently are analagous to the antheridia and pistillidia of other Cryptogamics. The former are pyriform sacs containing pollen-like grains, the others are similar sacs containing cells arranged in fours, one of which is developed as the embryo-plant. In Salvinia, as shown in Figure 951, page 317, the antheridia and the ovules or pistillidia are in distinct involucres or sporocarps, supported on cellular columns.

2. ORGANS OF MOSSES AND THEIR ALLIES.

446. *Mosses* or *Musci.*—These plants have stems bearing minute cellular leaves. The stems consist of cells which in the periphery are polyhedral, while in the centre they are elongated. There is no pleurenchyma nor true vascular system. In many Mosses the stem terminates at a certain epoch, by bearing the organs of reproduction. Such stems are determinate, and the Mosses are called *acrocarpous* (fruit at the summit). In other cases the principal stem ends in a leaf-bud, and continues to elongate, the organs of reproduction appearing on lateral branches. Such stems are indeterminate, and the Mosses are called *pleurocarpous* (fruit at the side).

447. The leaves, when produced on the stem, are called *caulinary*; when they surround the reproductive organs they are called *perichætial* (around the seta). The latter are usually more approximated than the others, and form a sort of rosette, in the centre of which the reproductive organs are situated. The leaves are very thin in their texture, and are frequently composed of a single cellular layer. The cells usually contain chlorophylle, but sometimes, as in Sphagnum, they are colourless. The cells are either uniform in their size and appearance, or a certain number towards the centre are elongated, so as to form veins or ribs. The phyllotaxis of Mosses is usually $\frac{1}{2}$, $\frac{2}{5}$, or $\frac{3}{8}$. Buds, or what are called *innovations*, are often produced in the axil of the leaves. These buds, when detached, become new plants.

448. Occasionally the reproductive organs of Mosses have a peculiar leafy covering or *perigone*, formed by the adhesion of three or six small leaflets, which are quite distinct from the perichætial leaves.

The organs of reproduction are of two kinds: one, consisting of cylindrical, pear-shaped, or ellipsoidal stalked sacs, containing minute cells, with phytozoa or spermatozoids in their interior; the other being also stalked sacs, of a more or less spherical form, containing germinating spores. The former constitute the antheridia, the latter the pistillidia or archegonia. These organs sometimes exist together on the same

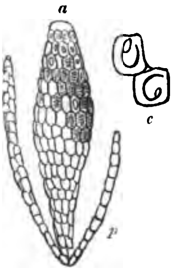

Fig. 1000.

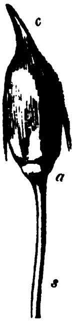

Fig. 1001.

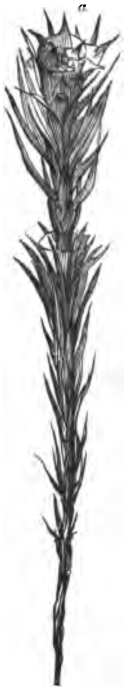

Fig. 999.

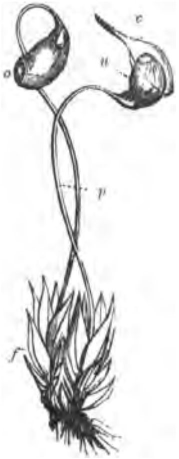

Fig. 1003.

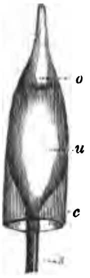

Fig. 1002.

Fig. 999. Antheridium-bearing plant of Hair-moss (*Polytrichum*). It consists of an axis bearing pointed leaves. At the apex of the axis, *a*, the leaves become altered in form and appearance, and cover cellular sacs with paraphyses. The former are antheridia, and are called the male organs. In this Moss the antheridia and pistillidia are on separate plants, hence it is called Diœcious.

Fig. 1000. The so-called male organs of the Hair-moss (*Polytrichum*). The antheridium, *a*, is a cellular bag containing minute quadrangular cells, *c*, each enclosing a spiral phytozoon or spermatozoid. Surrounding the perfect antheridium there are abortive filaments, *p*, called paraphyses.

Fig. 1001. Fructification of the Hair-moss (*Polytrichum*), consisting of an urn-like (urceolate) case or sporangium, *a*, supported on a stalk (seta), *s*, and covered by a calyptra, *c*, which has on its exterior silky hairs, and which splits irregularly at the base.

Fig. 1002. Fructification of the Extinguisher-moss (*Encalypta vulgaris*), consisting of an urceolate sporangium, *u*, supported on a seta, *s*, and covered by a transparent calyptra, *c*, under which is seen the lid or operculum, *o*. The calyptra is entire at the base, and is called mitriform.

Fig. 1003. Hygrometric Cord-Moss (*Funaria hygrometrica*), with its urn-like sporangia, *u*, supported on stalks, *p*, which arise from perichætial leaves, *f*. The sporangia are covered by a calyptra, *c*, which splits on one side. The operculum or lid, *o*, is seen in one of the sporangia from which the calyptra has fallen. The seta is twisted, and displays hygrometric properties.

plant; at other times they are on separate plants. In the former case the Mosses are monœcious, in the latter diœcious. When both these organs are not only on the same plant, but also surrounded by the same perigone, the term hermaphrodite has been applied by some.

449. The antheridia of Mosses are produced from little clusters of leaves, which differ from those of the stem (Fig. 999, *a*). They appear in the form of cellular, cylindrical, clavate bodies (Fig. 1000, *a*), containing at first a mucilaginous fluid, and finally very minute quadrilateral cellules, *c*, (sometimes called *zoothecæ*), in each of which a spiral phytozoon is seen. The antheridia dehisce by irregular openings at their apex, so as to discharge their contents (Fig. 1000, *a*). Along with the antheridia there are cellular jointed filaments (Fig. 1000, *p*) called *paraphyses*, which are considered to be an abortive state of these organs.

450. The archegonia, often mixed with paraphyses or abortive filaments, arise also from small clusters or rosettes of leaves (Fig. 1003, *f*), and appear in the form of spherical or obovate bodies having an outer envelope (epigone) and a central cellular nucleus. In the progress of growth, the central portion increases and rises upwards, and, at the same time, the epigone is ruptured near the base—one portion of it remaining below in the form of a small sheath (vaginula), the other being carried up on the fruit-bearing stalk in the form of a *calyptra* (Fig. 1001, *c*). This calyptra is sometimes split at one side (Fig. 1003, *c*) so as to become *dimidiate* (halved), and at other times it is either entire (Fig. 1002, *c*) or split equally all round the base, and it is then called *mitriform*. The nucleus or central portion, when fully developed, constitutes the *sporangium* or fructification. The sporangium is usually supported on a stalk or *seta* (Fig. 1003, *p*), formed by the lower cells of the nucleus. The seta is often twisted, and, from its hygrometric properties, it produces changes in the position of the sporangium, according to the state of dryness or moisture of the atmosphere. A species of Funaria or Cord-moss, receives the name of *hygrometrica*, on account of these properties. The seta varies in length: sometimes it is very short, as in Phascum; at other times long, as in Polytrichum (Fig. 947, p. 316).

451. The sporangium in its young state is a mass of cellular tissue, the cells of which are homogeneous, and contain green matter. When mature, it is an urn-like body (Fig. 1003 and 1004, *u*), with a cellular central axis called *columella*, and a cavity containing spores. In some instances the sporangium is indehiscent; in other cases it opens either by four lateral valves, as in the Split-moss (Andræa), or by means of a lid called an *operculum* (Figs. 1004, *o*, and 1005, *o*). The walls of the sporangium consist of three cellular layers, which may be looked upon as three urns contained within each other, the innermost, next the spores, being less deep than the others. The outer layer, prolonged upwards, forms the operculum or lid, which separates by transverse dehiscence. The two outer layers some-

times become much swollen at the base, where the sporangium joins the seta, and give rise to a cellular mass called an *apophysis*. Sometimes there is only a thickening at the union of the seta and urn (Fig. 1001, *a*); at other times there is a swelling at one side.

452. When the operculum is removed, the opening (stoma or mouth) of the sporangium is seen. This is sometimes entire, as in Mosses called naked-mouthed (gymnostomi); at other times it is surrounded by a *peristome*, formed by prolongations and divisions of the two inner parietal layers of the sporangium (Fig. 1006, *p*). The peristome consists of one or more rows of hygrometric cellular *teeth*, which are either four, or some multiple of that number. When there is one row of teeth, the Mosses are called *aploperistomi* (having a single peristome); when there are two rows, the Mosses are called *diploperistomi* (having a double peristome). The peristomatic processes

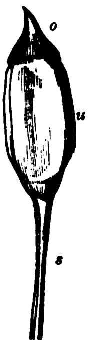

Fig. 1004.

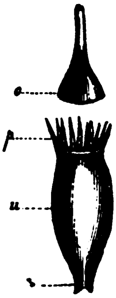

Fig. 1005.

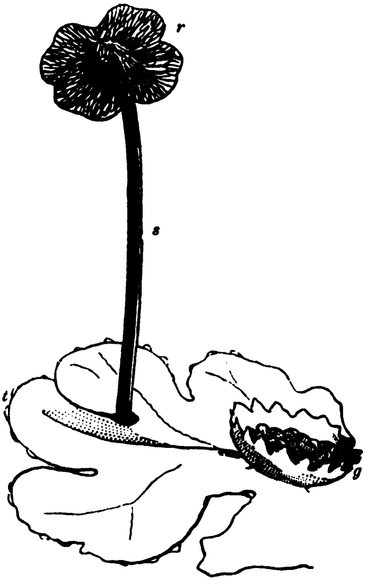

Fig. 1007.

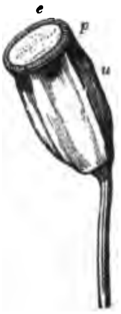

Fig. 1006.

Fig. 1004. Sporangium, *u*, of Hair-moss (*Polytrichum*), deprived of its calyptra, and showing the operculum or lid, *o*, at the summit. The sporangium is supported on a seta, *s*.

Fig. 1005. Sporangium, *u*, of the Extinguisher-moss (*Encalypta*), with its seta, *s*, operculum or lid, *o*, which is removed so as to exhibit the peristome, *p*, with its sixteen processes or teeth.

Fig. 1006. Sporangium, *u*, of Hair-moss (*Polytrichum*), supported on its seta, *s*, and deprived of its calyptra and operculum. Surrounding the apex is the peristome, *p*, and closing the orifice is a membrane called the epiphragm, *e*.

Fig. 1007. A species of Liverwort (*Marchantia polymorpha*), with its green thallus, *t*, bearing a cup-like body, *g*, in which minute cells or free buds (sporules of some) are seen, and a stalked receptacle, *s r*. In the substance of the disk-like receptacle, *r*, cells are produced containing phytozoa These are considered antheridia.

(teeth) are sometimes twisted as in Tortula. In some Mosses the inner parietal layer appears as a membrane called *epiphragm* or *tympanum*, stretched across the mouth, from the walls of the sporangium to the columella (Fig. 1006, *e*). The lid is composed of a single cellular layer, and may be considered a continuation of the outer sporangial wall. It is generally, however, separated from the sporangium by two or three rows of cells, forming a ring or *annulus*. The inner lining of the sporangium encloses sporiferous mother-cells, the contents of which divide into four spores.

453. Some consider the sporangium as formed of a series of cellular leaves, arising from the top of the seta, and united together, the lid being formed by the laminæ, which are joined by an articulation to the petiole, in the same way as occurs in the Orange leaf. The teeth are regarded as instances of chorisis; while the calyptra is said to be a convolute leaf or bract, covering the spore-case in its young state. In some rare instances it is said that leaves are produced in place of spore-cases. Henfrey considers the pistillidia of Mosses as resembling the so-called ovules of Club-mosses and Rhizocarps—the pistillidia giving rise to sporangiferous individuals. There is thus a compound organism, in which a new individual, forming a second generation, developed after a process of fertilization, remains attached organically to its parent, from which it differs totally in all anatomical and physiological characters. It is an instance of alternation of generations. This, he says, is quite different from buds in Phanerogamia. It is not merely an extension by gemmation. The sporangia of Mosses are the result of a truly reproductive process, while the innovations are buds.

454. The spores of Mosses, when sprouting, give out filaments which ramify and anastomose. These filaments, being composed of cells placed end to end, and being filled with green matter, resemble Confervæ. After fifteen or twenty days, there are seen at numerous points, where the filaments cross, small leaves disposed regularly round a very short axis. In this process Mosses resemble fungi. In both the spores give origin to filaments, and from these filaments the characteristic organs of the plant arise. In the latter, however, the filamentous cells, called the mycelium, never contain green matter; while the filaments of Mosses always do. The mycelium of Fungi performs almost entirely the function of nutrition, and often remains during the life of the plant; while the filaments of Mosses perform only temporary functions, and are replaced by proper leaves, stems, and roots, which give origin to the reproductive organs.

455. *Liverworts or Hepaticæ.*—In these plants, the vegetative system (organs of nutrition) consists either of a simple membranous expansion, composed of united cells, containing green matter, or of an axis bearing cellular leaves. In Marchantia, this membranous expansion or *thallus* (Fig. 1007, *t*) is composed of several layers of cells. The upper and lower layers consist of colourless cells, and form a sort

of epidermis. The upper epidermal layer has stomata, while the lower gives off root-like filaments. The central layer of cells contains green matter, and between the cellules there are spaces which communicate with the stomata on the upper surface. Those Liverworts which have a thallus such as Marchantia, are called *membranous;* while those having stems and leaves, such as the Scale-mosses (Jungermanniæ), are *caulescent.* In the latter the leaves present various forms, such as oval, entire, bidentate, bifid, two-lobed, quadripartite, and laciniated.

456. The thallus of Marchantia differs from the foliaceous expansion of Lichens, in its mode of production. In the latter, the spore, when sprouting, gives out filaments like the mycelium of Fungi, whence the foliaceous receptacle is produced; while in the former the spore is at once developed as a cellular mass, of a more or less irregular form, in the same way as occurs in Sea-weeds. The thallus of Marchantia, besides producing organs of reproduction, bears cup-like bodies with toothed edges, containing little germs or bulbils (the sporules of some authors), which are not traced to a reproductive process, and differ from buds, in being contained in peculiar organisms. These *sporules*, *bulbils*, or *germs*, propagate the plant. They are seen in Fig. 1007, *g*, on the surface of the thallus. Besides these, there are innovations, or true buds, which are produced from the edges of the principal thallus in membranous Liverworts, and from the axil of the leaves in the caulescent Liverworts. These buds, when detached, give origin to new individuals.

457. In Hepaticæ, the reproductive organs consist of *zoothecæ* or *antheridia*, and *archegonia* or *pistillidia*, either on the same or on different plants. The antheridia are small cellular sacs of a globular, ovoid, or flask-like form. They have a single or double cellular covering, enclosing viscid matter, in which are developed four-sided cells, in each of which is a small filiform body, rolled up in a circular manner, and displaying rapid movements. These bodies, called *phytozoa*, are finally liberated, and unrol themselves, appearing as filaments swollen at one extremity, and gradually tapering to the other. In Marchantia (Fig. 1007), these antheridia occur in the upper side of an elevated disk or receptacle, *r*. When this disk is cut vertically, as shown in Figure 1008, they are seen at *a a*, as flask-like cellular sacs, separated by air cavities, *c c*, which communicate with stomata, *s s*. A magnified antheridium discharging its phytozoary cells, is given in Figure 1009. In some Hepaticæ these antheridia occur in the substance of the thallus, while in others (as in some Jungermanniæ) they appear in the axil of the leaves.

458. The archegonia or pistillidia of Hepaticæ are either situated in the substance of the thallus, as in Riccia, or they are raised upon stalks, as in Marchantia (Fig. 1010) and Jungermanniæ. In Marchantia these stalks bear radiated receptacles, *r*, on the under surface of which the sporangia are placed. These sporangia have a membranous

covering called *epigone* or *calyptra*, the upper end of which elongates like the neck of a bottle (Fig. 1011, *a*), so that the pistillidium resembles a pistil, with its ovary, style, and stigma. When the sporangium is raised on its stalk, the calyptra is ruptured irregularly; its lower portion remaining in the form of a sheath round the base of the stalk. The pistillidium, thus formed by the central cellular spore-

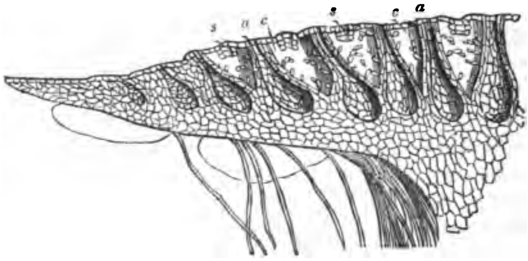

Fig. 1008.

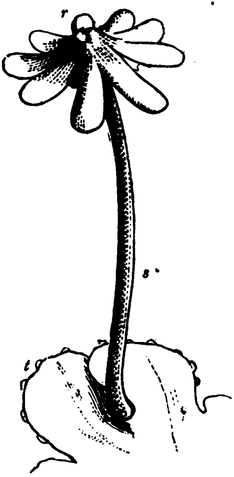

Fig. 1010.

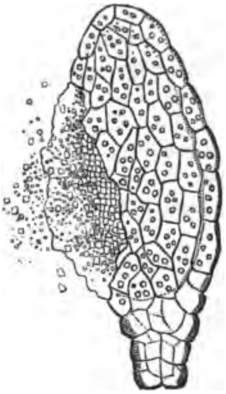

Fig. 1009.

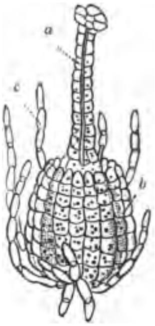

Fig. 1011.

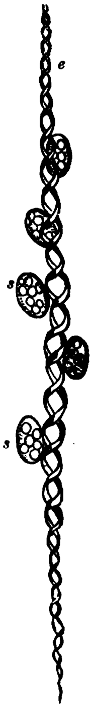

Fig. 1012.

Fig. 1008. Vertical section of the disk-like receptacle of Liverwort (*Marchantia*), showing the antheridia, *a a*, in its substance. These antheridia are flask-shaped sacs containing phytozoary cells. They communicate with the upper surface, and their contents are discharged through it. Between the antheridia there are air cavities, *c c*, connected with stomata, *s s*.

Fig. 1009. Antheridium of Liverwort (*Marchantia*) ruptured, and discharging its cellular contents.

Fig. 1010. A species of Liverwort (*Marchantia polymorpha*), with its thallus, *t*, bearing a stalked receptacle, *s r*. The receptacle, *r*, is divided into numerous segments, on the under side of which are sporangia containing spores and elaters.

Fig. 1011. Pistillidium of Liverwort (*Marchantia*). It is a cellular body surrounded by an involucre (perigone or calyx), *b*, and septate filaments (paraphyses), *c*, and it is provided with a styloid calyptra, *a*.

Fig. 1012. Spiral threads or elaters, *e*, of Liverwort (*Marchantia*), originally contained in the sporangia, and serving, by their elasticity, to scatter the sporidia, *s s*.

bearing sac and the epigone, is surrounded also by a cellular sac called the *perigone* (Fig. 1011, *b*), which begins in the form of a ring at the base, and ultimately forms a cup-like covering. Occasionally there are certain cellular filaments, or perichætial leaves, surrounding the perigone (Fig. 1011, *c*). In Marchantia the perigone encloses a single pistillidium; in Jungermannia it encloses several, but only one is developed.

459. The structure of the sporangium, or the sac containing the mother-cells of the spores, varies in different genera. In Anthoceros, the sporangia are elongated and open by two valves, and there is a central cellular columella. In Jungermannia, the sporangia are globular, and open by four spreading valves. There is no central column, but the inner wall displays cellules, called elaters, fixed by one extremity, and containing one or two spiral fibres which by their elasticity scatter the spores. In Riccia, the sporangia are globular, and there are neither elaters nor columella. In Marchantia, the sporangia consist at first of a mass of cellular tissue containing green matter. There are two sets of cells, one internal, being the spore-cells, and the other external. The latter display polyhedral and rounded cells along with slender fusiform tubes, the walls of which are marked by two spiral striæ, which ultimately appear as two cork-screw like threads (Fig. 1012). These threads or *elaters* are very hygrometric, and serve to scatter the spores. In the Hepaticæ, in general, the spores are developed in spheroidal mother-cells, the contents of which divide into four parts, each of which is a germinating spore. The spores become free by the destruction of the walls of the mother-cells.[*]

3. Organs of Lichens and their Allies.

460. *Lichens or Lichenes* are cellular plants growing on stones, on the surface of the earth, and on trees, and taking up nourishment by all points of their surface. They belong to the Thallogenous division of Cryptogamics, in which no vascular tissue is seen. Their vegetative system varies much in its form and appearance. Sometimes it appears as fine pulverulent matter in the form of a leprous or mealy crust; sometimes it is a foliaceous expansion, as in Parmelia (Fig. 1013) and in Iceland Moss (Fig. 1014); sometimes it is in the form of filaments, as in Archil (Fig. 1015), of horn-like processes, or of branching stalks, as in the Rein-deer Moss (Fig. 1016); and sometimes it is a gelatinous mass.

[*] For further particulars relative to the structure and development of the members of the Muscal alliance, consult Hedwig, Theoria Generationis et Fructificationis Plantarum Cryptogamicarum, and Fundamentum Historiæ Naturalis Muscorum Frondosorum. Cassebeer, ueber die Entwickelung der Laubmoose. Beninga de Evolutione Sporidiorum in Capsulis Muscorum. Bruch and Schimper, Bryologia Europæa. Lindenberg, Species Hepaticarum. Gottsche, Synopsis Hepaticarum. Mohl, sur le Developpement des Spores de l'Anthoceros Lævis, Ann. des Sc. Nat. 2d ser. xiii. 208. Valentine on Mosses, Linnæan Transactions, xvii. 465. Montagne, des Organes Males du Genre Targionia, Ann. des Sciences Nat. 2d ser. ix. 100. Hooker's British Jungermanniæ. Mirbel, Recherches Anatomiques et Physiologiques sur le Marchantia Polymorpha, in Nouv. Ann. du Museum, i. 93.

461. The vegetative system is sometimes called the *common receptacle*, at other times it is called *thallus*. The latter term is by some authors restricted to the vegetative system of Liverworts and Seaweeds—the foliaceous expansion of Lichens being considered by them as produced from anastomosing filaments, forming a sort of mycelium or spawn, which, after serving a temporary purpose, disappears. The vegetative system of Lichens consists of two kinds of cells, cylindrical and spherical. When the common receptacle (thallus) spreads on the surface of bodies, the cylindrical cells are on the lower surface, and the spherical on the upper. When the common receptacle is vertical, the spherical form the external portion, and the cylindrical the central.

462. There are two layers of tissue usually distinguished in Lichens, one called *cortical*, in which the cells are more or less rounded, the other medullary, in which there are both round and filiform cells. The spherical cells of the medullary layer (Fig. 1020, *g*) are generally filled with green matter, and, in certain circumstances, they become detached and form separate individuals. These green cells have received the name of *gonidia*. When they are being detached, the separation begins at the centre, so that the middle of the Lichen becomes pulverulent, while its circumference may remain foliaceous or crustaceous. By the continuation of this process it sometimes happens that the whole Lichen becomes a mass of greenish or yellowish powder. The gonidial cells seem to be the active vegetating part of the Lichens, and give rise to the other tissues. They may be considered as germs not produced by a process of impregnation.

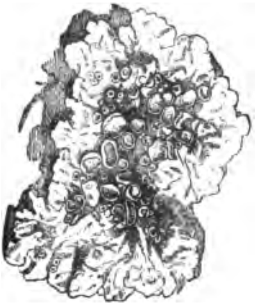
Fig. 1013.

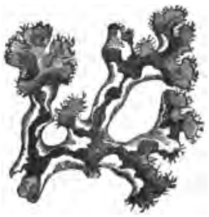
Fig. 1014.

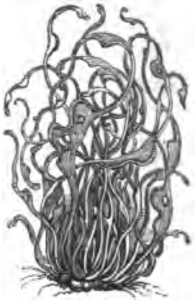
Fig. 1015.

463. The reproductive organs of Lichens consist of *thecæ* (sporangia of some), often accompanied with paraphyses. While these represent the archegonia or pistillidia, there is no good evidence of

Fig. 1013. A Lichen (*Parmelia*), with its cellular expansion (thallus), and its rounded apothecia, or spots of fructification.

Fig. 1014. Iceland Moss (*Cetraria islandica*), a species of Lichen, consisting of a foliaceous cellular expansion bearing the fructification.

Fig. 1015. Archil (*Roccella*), a species of Lichen used to furnish Litmus. It consists of thread-like cellular expansions, bearing fructification.

the existence of true antheridia. Itzigsohn has recently indicated the presence of antheridia containing spermatozoids, but his observations have not been confirmed by Tulasne and others.* The thecæ contain four, eight, twelve, or sixteen sporidia (Fig. 1017), which are cells with spores in their interior. The sporidium in its early state consists of two nucleated cells (Fig. 1018), which in the progress of growth become changed (probably by a process of conjugation), so that ultimately the mature sporidium contains numerous minute spores. In Figure 1017, *t*, there is represented a theca or *ascus*, as it is often called, with four sporidia in its interior, and surrounded by paraphyses or abortive filaments, *p*.

464. The thecæ and paraphyses are usually united together, so as to form a mass of fructification of a circular, cup-like, globular, or linear form. The fructification, when circular, is called *apothecium* and *patella* (Figs. 1019 and 1020, *a*), when linear, *lirella*. Sometimes the fructification is covered by a cortical layer of cells (perithecium), varying in colour, black, red, or pale, which ultimately gives way, either by a pore or by irregular dehiscence. This is seen in what are called *Angiocarpous* Lichens. In them there is a nucleus in the centre of the fructification, which consists of hyaline tubes or asci, each of

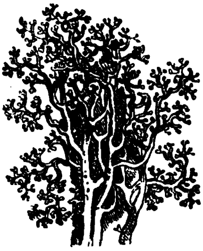

Fig. 1016.

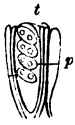

Fig. 1017.

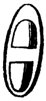

Fig. 1018.

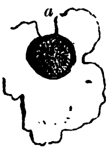

Fig. 1019.

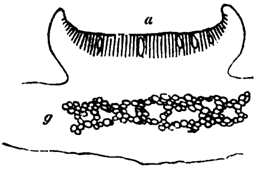

Fig. 1020.

Fig. 1016. Rein-deer Moss (*Cladonia rangiferina*), a species of Lichen on which the rein-deer feeds. It consists of branching cellular filaments bearing the fructification. The Lichen has a coral-like aspect.

Fig. 1017. A theca, *t*, of a Lichen, containing four nucleated cells. These cells ultimately form the sporidia or sacs containing numerous minute spores. Round the theca are cellular filaments or paraphyses, *p*.

Fig. 1018. A cell taken from the theca or ascus of a Lichen. It contains two smaller cells in its interior, which some botanists consider as conjugating cells. The large cell ultimately constitutes the sporidium filled with minute spores. Some have called the sporidium in this condition a bispore or bilocular spore.

Fig. 1019. Portion of the cellular expansion (thallus) of a Lichen, bearing a rounded mass of fructification *a*, called apothecium.

Fig. 1020. Vertical section of an apothecium and thallus of a Lichen. Rounded free cells, *g*, of a green colour, and called gonidia, are seen in the centre of the thallus. These gonidia, which are called free buds by some, are capable of germinating and reproducing the plant. They constitute the active part of the Lichen, and are surrounded on each side by integumentary layers. Sometimes they burst through the surface of the thallus. The apothecium, *a*, consists of thecæ and paraphyses. Its upper surface is often coloured and covered by a perithecium.

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* Comptes Rendus, March 24, 1861.

which contains eight *sporidia*. When mature, the sporidia and asci are ruptured, so as to discharge numerous minute spores through the pore or perforation at the apex of the perithecium. When the fructification bursts through the cortical layers, and appears externally, it is either completely distinct from the cortical layer, or a portion of the latter remains in the form of an elevated border. Sometimes the superficial cellular layer produces a stalk called *podetium*, on which the fructification is supported. The extremities of the paraphyses are often swollen and coloured, so as to give rise to the peculiar colour of the apothecia.*

4. Organs of Fungi and their Allies.

465. *Fungi* are cellular plants having neither leaves, nor stems, nor roots. The organs of nutrition or vegetation consist of whitish anastomosing filaments called *mycelium* or spawn (Fig. 1021, *m*), which spread like a network through the substances on which the Fungi grow. From this network proceed bodies resembling globes, circular disks, mitres, cups, and coralline branches, which bear the organs of reproduction. The mycelium is developed either under ground, or in the interior of the substance on which the plant grows. The filaments of the mycelium are composed of elongated colourless cells. This peculiar condition of Fungi has sometimes been mistaken for their perfect state, and hence the spawn has been described in some cases as a separate genus. It is necessary to watch the various phases of development in this order of plants in order to give a correct view of their organization and their characters.

466. The organs of reproduction are produced at different points of the mycelium, sometimes solitary, sometimes several together. They at first appear as small tubercles composed of very minute hexagonal cells. These tubercles increase and present different phenomena according to the nature of the plant to which they belong. Thus in Ægerita, the tubercle, after attaining its full development, is covered with filaments, each bearing a spore at its extremity; in Peziza, it is hollowed out into the form of a cup more or less deep, the interior of which is lined with thecæ or asci; in Agaricus, it produces a pileus or cap-like body borne on a long stalk which comes from the interior of the tubercle, and bears the fructification externally; in Lycoperdon it forms in its tissue numerous lacunæ, from the circumference of each of which are produced elongated cells bearing four spores on their surface.

467. The mycelium requires a certain amount of moisture and heat for the development of the reproductive tissue. Sometimes it remains

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* For further particulars as to Lichens, consult Meyer, ueber die Entwickelung der Flechten. Fries, Lichenographia Europæa. Fée, Methode Lichenographique, and Essai sur les Cryptogames des Ecorces officinales. Eschweiler, systema Lichenum. Leighton, on the British species of Angiocarpous Lichens, printed by the Ray Society 1851.

long in a dormant state, with tubercles on its surface, and in this condition it presents some of those forms described as Sclerotium by botanists. The tubercles remain under ground, or under the epidermis of leaves, or the bark of trees, and in these situations they undergo certain changes. Under favourable circumstances the changes are very rapid, and the tissue bearing the reproductive organs springs up with amazing rapidity. This is well seen in the case of Mushrooms, Puff-balls, and Phallus. The mycelium itself spreads with great rapidity, as is familiarly seen in Mushroom spawn. It may be kept long in a dry state, ready to develope the reproductive apparatus whenever heat and moisture are applied.

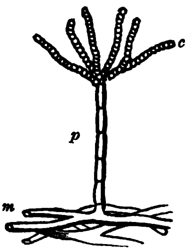


Fig. 1021.

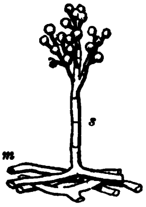


Fig. 1025.

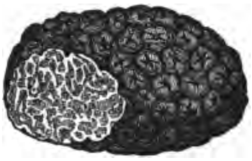
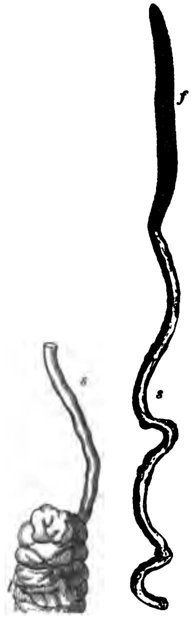


Fig. 1022.



Figs. 1023, 1024.

468. Some Fungi vegetate under the surface of the ground, and either produce their fructification there, as the Truffle (Fig. 1022), or above ground, as the Mushroom (Fig. 1031). A very large number,

Fig. 1021. A species of Mould (*Penicillium*), consisting of a mycelium or spawn, *m*, whence arises a fructiferous stalk, *p*, bearing several rows of cells, *c*, united in a bead-like (moniliform) manner. These minute cells are the germinating spores.

Fig. 1022. The Truffle (*Tuber cibarium*), a subterranean Fungus, with a black tuberculated or warty external covering, and a white cellular interior containing sporiferous cells.

Figs. 1023 and 1024. Specimen of a New Zealand Fungus (*Sphæria Robertsii*), growing from the head of a caterpillar (the larva of Hepialus virescens), *l*. The stalk, *s s*, bearing the fructification, *f*, in a spike-like form at its extremity. The growth of the Fungus destroys the caterpillar.

Fig. 1025. A species of Mould-fungus (*Botrytis*), consisting of a mycelium, *m*, bearing a septate cellular stalk, *s*, which branches at the apex, each division bearing a rounded spore.

however, are developed as parasites in the interior of living or dead organised bodies. Many of them give rise to diseases in plants. Some Fungi are produced in animal tissues, more especially in certain diseased conditions of the epidermal system or of the mucous membranes. Their presence in such cases seems to cause an alteration in the phenomena of disease. In Figures 1023 and 1024 is shown a species of Sphæria growing on the larva of a New Zealand insect called Hepialus virescens. Such fungoid growths often cause the destruction of the insect on which they grow, and, in the case of the silk-worm, they give rise to serious loss.

469. The organs of reproduction of Fungi are spores which are either naked or are contained in thecæ or asci, and which are mixed with certain filaments called antheridia. Little is known in regard to the latter. When spores are produced in the interior of distinct sacs, called *thecæ* or *cystidia* (Fig. 945, *cys*, p. 314), they are denominated *endospores*, and the plants are said to be *thecasporous;* when they are developed on the exterior of sacs called *basidia*, they are denominated *exospores*, and the plants are *basidiosporous;* when produced in the midst of a gelatinous mass, without any evident organization, they are called *myxospores*, the plants being *myxosporous.*[*]

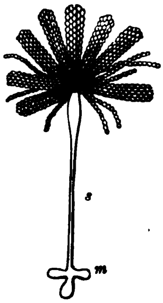


Fig. 1026.

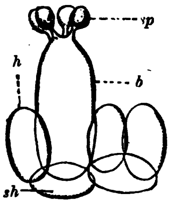


Fig. 1027.

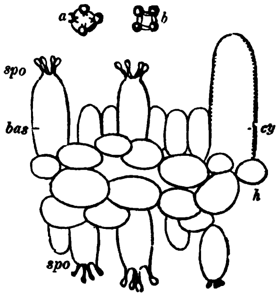


Fig. 1028.

470. In Basidiosporous or Exosporous Fungi, there are different modes of spore-development. In the filamentous Fungi (Hyphomy-

Fig. 1026. Blue mould, a species of Fungus (*Aspergillus glaucus*), having a mycelium, *m*, whence arises a stalk, *s*, bearing numerous rows of sporiferous cells developed from a common centre, which is the swollen extremity of the stalk or floccus.

Fig. 1027. Part of the fructification of the Mushroom (*Agaricus campestris*). The cellular stratum, bearing the fructification or hymenium is marked *h*, and below it is the sub-hymenial layer, *sh*. A basidium or basidial cell, *b*, bears at its apex four spores, *sp*, which are supported on stalks or sterigmata. The Fungus is basidiosporous, and it has a naked hymenium.

Fig. 1028. Portion of a lamella or gill of the Mushroom (*Agaricus campestris*), cut transversely showing the two lateral surfaces bearing basidia, *bas*, with four spores, *spo*, at their apices, and cystidia, *cys*, or sacs containing minute cells. The hymenium is marked *h*. At *a* and *b* are represented the four spores.

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[*] Berkeley thinks that in certain Fungi the asci are converted into spores. See Reports of Brit. Assoc. for 1851.

cetes), the terminal cell of a filament sometimes is transformed into a spore, as in Botrytis (Fig. 1025); at other times several of the terminating cells are transformed so as to produce a series of spores like a row of beads, as in Torula and Penicillium (Figs. 1021 and 1026). In the Agarics and Puff-balls, four small prominences appear on the basidium, which elongate and finally become four stalked spores (sporophores), as seen in Figures 1027, *sp*, and 1028, *spo*. In Thecasporous Fungi, the sac or cystidium is either a globular body containing a great number of spores (Fig. 1029, *s*) disposed without order, as in some of the Mucors (Ascophora mucedo); or it is of an ovoid or clavate form, containing four, six, or eight spores or sporidia placed one above the other, as in Peziza (Fig. 1030). This class of Fungi is included among the Lichens by Schleiden, who considers all true Fungi as having free naked spores, *i.e.*, as being basidiosporous.

471. The fructification is composed either of a single transparent colourless cell, of a rounded or spindle-like form, at the end of each filament (Fig. 1025); or it is composed of several cells united in a linear series (Figs. 1021 and 1026) or irregularly. The cystidia and basidia are either monosporous or tetrasporous (Figs. 1027 and 1028).*

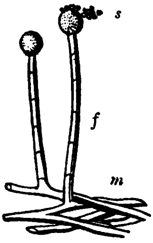

Fig. 1029.

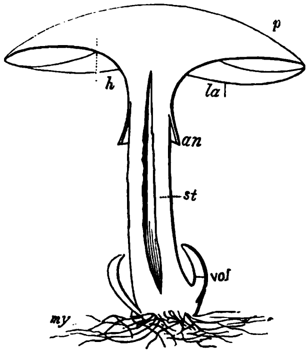

Fig. 1031.

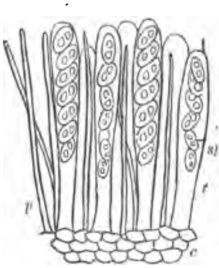

Fig. 1030.

Fig. 1029. A species of Mould (*Mucor*), showing the mycelium, *m*, bearing a fructiferous stalk, *f*, ending in a sac or cystidium, *s*, which encloses numerous very minute spores. The spores are discharged by the bursting of the sac.

Fig. 1030. Vertical section of the fructification of a Fungus (*Peziza*), showing the cellular stratum, *c*, bearing clavate spore-cases or thecæ, *t*, which contain nucleated cells, *sp*. These cells ultimately become sporidia, containing spores. Along with the thecæ are cellular filaments or paraphyses, *p*.

Fig. 1031. Vertical section of a Mushroom (*Agaricus campestris*); *my*, mycelium or spawn; *vol*, remains of volva or wrapper, which covers the fructification in the young state; *st*, stipe or stalk, which is hollow internally; *an*, annulus or ring, being the remains of the velum, veil, or cortina, which extended from the edge of the pileus to the stipe; *la*, lamellæ or gills of the hymenium, *h*; *p*, the pileus.

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* The spores of Fungi are very minute. In the case of Moulds, millions of them are required to make a body the size of a pin-head. They float about in the air, and, owing to their minuteness, cannot be detected.

When either of these kinds of fructification are united into a mass along with paraphyses, they form what is called the *hymenium* (Fig. 1030). The hymenium is either naked, as in the Hymenomycetous Fungi, or it is enclosed in a membrane called *peridium*, as in Gasteromycetous Fungi. This membranous covering may be either single or double.

472. The hymenium bearing the organs of reproduction sometimes consists of vertical plates or laminæ radiating from a centre, as in the Agarics, or of tubes, as in Polyporus, or of solid columns, as in Hydnum. Sometimes it is covered by a membranous expansion called an *indusium*, which gives way in the progress of growth. Sometimes it is placed on the lower surface of a disk-like body called the *pileus* or cap, as in the Mushroom; at other times it is on the upper surface of the pileus, as in Helvella.

473. In the Mushroom (Fig. 1031) and other species of Agaricus, the following are the usual organs observed:—A mycelium or spawn, *my*, developed under ground, bearing tubercles which consist of the reproductive organs enclosed in a *volva* or wrapper. This volva, *vol*, is ruptured in the progress of development. The Agaric is then seen to be composed of a pileus, *p*, supported on a stalk, *st*, called a *stipe*. On the lower side of the pileus is the lamellar hymenium or gills, *la*, bearing spores. The hymenium was first covered by the veil or indusium, which finally gives way, leaving only a ring, *an*, round the stalk.*

5. ORGANS OF ALGÆ AND THEIR ALLIES.

474. *Algæ* include a great number of plants which grow in the sea, in rivers, lakes, marshes, and hot springs. Their structure is such that they can only grow in water; when exposed to the air they wither and cease to grow. They have no true leaves and no proper stem, but consist of a thallus or cellular expansion which varies in colour—being brown, red, green, or yellow. In some of the larger Sea-weeds, as Durvillea utilis and Lessonia fuscescens, the thallus is supported on a thick stalk, which exhibits in its structure the appearance of concentric circles. These stalks, however, are composed entirely of cellular tissue arranged in a peculiar manner. There is no vascular system and no woody fibre in their composition. Some species have root-like processes by which they are attached to rocks. These are only intended for fixing them to a spot so as to allow the fronds to be properly exposed to the water, and they do not appear to act as special nutritive organs. The structure of Algæ is cellular, and

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* For further details relative to Fungi, consult Berkeley on the Fructification of Fungi, Ann. Nat. Hist. i. 81, and Ann. des Sc. Nat. 2d ser. Bot. xii. 160. Montagne, Esquisse Organographique et Physiologique des Champignons. Leveillé, sur l'Hymenium des Champignons, Ann. des Sc. Nat. 2d ser. Bot. viii. 321; and Recherches sur les Uredinées, Ann. des. Sc. Nat. 2d ser. Bot. xi. 5. Tulasne, Fungi Hypogæi; also various papers by him in Ann. des Sc. Nat. 2d ser. Bot. xvi. 5, xvii. 5, xviii. 129, xix. 373, and 3d ser. Bot. i. 41, vii. 12. Dutrochet, sur les Champignons, in Ann. des Sc. Nat. 2d ser. Bot. i. 50, and Nouv. Ann. du Museum, iii. 76.

the cells vary much in form. Some of the cells are round or elliptical, others square, others elongated. The absorption of nourishment takes place throughout the whole substance of the thallus. On the surface of some Algæ, as the Charas, carbonate of lime is deposited, and sometimes, as in Corallines, the whole texture is so permeated by this substance, as to become of a hard and stony consistence.

475. In Algæ the reproductive organs vary in their appearance. They consist of spore-cases, which are often aggregated together in *conceptacles* (Fig. 1032, *p*), along with *antheridia* containing spermatozoids (Figs. 1033 and 1034). The spores are often united in fours in a mother-cell, forming a *tetraspore* (Fig. 1035, *t*). There are also present in many Algæ *zoospores* or *sporozoids*, which exhibit movements during a certain period of their existence, and are provided with filamentous vibratile processes (Fig. 1036). These moving spores have been particularly examined in Vaucheria ovoidea (Fig. 1037). This plant consists of an elongated cell, full of green matter, the extremity of which swells at a certain epoch, and exhibits a dark green mass, distinct from the rest of the green matter, and finally separated from it by a partition. The dark green mass is covered with a membrane or epispore, and then forms a spore of an oval form. This spore finally escapes from the end of the elongated cellular filament; and then it moves about in the fluid, by means of vibratile *cilia*, as they are called. The motions continue for some hours, until the spore fixes itself, and begins to sprout. These zoospores occur also in other genera of Algæ. The number of cilia varies, being numerous in Vaucheria, four in Chætophora elegans, and two in Conferva glomerata (Fig. 1038, 1, 2, 3). The antheridia are simple or double sacs, borne on tubes or filaments (Fig. 1033, *a*), which line superficial cavities or conceptacles, either along with sporiferous sacs, or alone. The same sac contains a number of phytozoa, having an ovoid or bottle-like shape, with two cilia, one

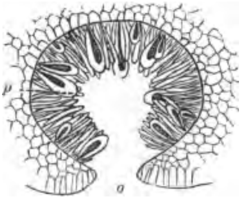

Fig. 1032.

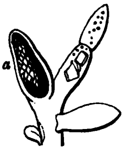

Fig. 1033.

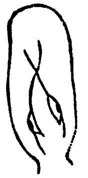
Fig. 1034.

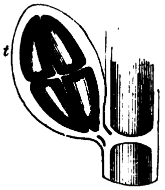

Fig. 1035.

Fig. 1032. Transverse section of a conceptacle of a Sea-weed (*Fucus vesiculosus*), showing the spores in their coverings, *p*, and paraphyses lining the cavity. The spores escape by an orifice, *o*.

Fig. 1033. Antheridium, *a*, or Zootheca of a Sea-weed (*Fucus serratus*), containing phytozoa. With the antheridium paraphyses are united in the same conceptacle.

Fig. 1034. Antheridium of a Sea-weed (*Fucus serratus*), still containing two phytozoa in the sac. To the broad part of the phytozoa two vibratile cilia are attached.

Fig. 1035. Tetraspore, *t*, of one of the rose-coloured Sea-weeds (*Callithamnion cruciatum*). It is a sac formed by the metamorphosis of the lowermost pinnule of the frond, and contains four germinating spores.

anterior and the other posterior (Fig. 1034), and having a fixed relation, as regards position, to a reddish granule situated towards the middle of the body.

476. In some of the lower plants of this order, such as Diatomaceæ (Fig. 1041), an evident division of cells takes place; and in this way the plants are propagated. In Protococcus, the plant of Red and Green Snow (Fig. 1039), and in Palmella, the plant of Gory Dew (Fig. 1040), and their allies, the whole plant separates into cells, which may be considered either as buds or spores. In these plants no special reproductive organs have been detected. In some of the Confervæ, as well as in Diatomaceæ, the union of cells takes place in a singular manner, so as to give rise to the formation of germinating spores (Fig. 1043).

477. *Brittleworts or Diatomaceæ.*—Among these are included some of the simplest forms of Algæ. They are usually composed of united rectangular fragments of a brittle nature, which separate at certain periods of growth, and form new individuals (Fig. 1041). The true Diatoms have a siliceous covering, so that they retain their form when dry, and are not destroyed by fire; while the division called Desmidieæ have no siliceous covering, and alter much on drying. In some of the plants of the order, the union of cells, called *conjugation*, has been observed, similar to what takes place in Confervæ. Many of the bodies included under this division of Algæ, were considered by

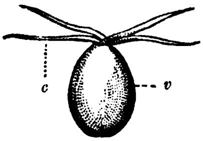

Fig. 1036.

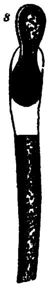

Fig. 1037.

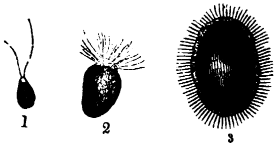

Fig. 1038.

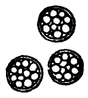

Fig. 1039.

Fig. 1036. Zoospore or sporozoid of one of the Confervæ (*Chætophora*). The spore consists of a vesicle, *v*, to which are attached four cilia or vibratile filaments *c*, which move for a certain time after the spore is discharged.

Fig. 1037. A Confervaceous Alga (*Vaucheria ovoidea*), consisting of an elongated club-shaped cell, full of green endochrome. The enlarged extremity contains a dark green mass, *s*, separated by a partition from the rest of the coloured particles. This dark mass becomes surrounded by a covering or epispore, and finally escapes through an opening in the apex of the filament. The spore, *s*, is provided with cilia, as seen in the next figure. The spore moves in the fluid around the plant for some time.

Fig. 1038. Zoospores or Sporozoids of Algæ. They are cellular bodies, provided with cilia or vibratile filaments. 1. Zoospore of Conferva, with two cilia at one end. 2. Zoospore of Conferva, with a tuft of cilia at one end. 3. Zoospore of Vaucheria, surrounded by cilia.

Fig. 1039. Cells of an Alga found in Green Snow (*Protococcus viridis*). It consists of a cell which performs the functions of nutrition and reproduction. It divides into various germinating cells, equivalent to spores, or, as some would say, to cellular buds.

Ehrenberg as of an animal nature, and he has figured them as such The division of the parent cell into two halves, is observed in a marked degree in Diatoms; and these halves afterwards become detached, so as to form distinct individuals.*

478. *Confervas and their Allies.*—These are plants usually of a green colour, consisting of round or cylindrical cells united (Fig. 1042), so as to form a filamentous or a flattened thallus. In their simplest form they are seen in the Palmella (Fig. 1040), consisting of a single globose cell, dividing first into two, and afterwards into four cells, which finally burst the mother-cell, and escape. Each of these divisions, like the parent cell, has the power of vegetating, and of dividing, by a merismatic process, into four, so as to multiply the plant. In Vaucheria, as already noticed (Fig. 1037), the terminal cell is concerned in the production of a germinating cell or spore, which has peculiar motions. In Achlya prolifera the terminal cell discharges numerous moving spores. In Zygnema and other Confervas (Fig. 1042), the cells composing the filaments have the power of giving out lateral cellular processes, by means of which a union takes place, the result being the production of a spore, either in the tube between the filaments, or in one of the cells of the filaments. The cells in these plants appear to have different functions, and to correspond to the antheridia and pistillidia of the higher Cryptogams. In Figure 1043 two filaments of Zygnema are seen united by tubes, *p*; the contents of one cell, *c*, are seen passing into another

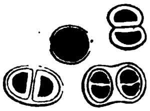
Fig. 1040.

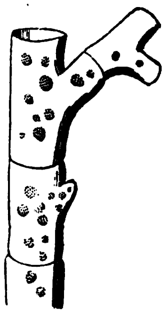
Fig. 1042.

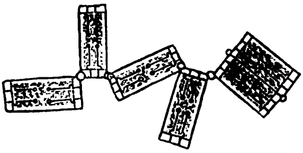
Fig. 1041.

Fig. 1040. Cells of the plant of Gory Dew (*Palmella cruenta*). The plant consists of a cell, which divides into two and then into four parts, each of which is capable of propagating the plant.

Fig. 1041. Frustules of a Diatomaceous Alga (*Diatoma marinum*), separating from each other in a merismatic manner. The frustules of the plant vary from nearly square to six times as long as broad, and they present two striæ.

Fig. 1042. Branching cellular septate filament of a Confervaceous Alga (*Chætophora*). The cells contain endochrome.

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* For valuable observations on these plants, see Ralfs on British Desmidieæ; also, on Diatomaceæ, in the Annals of Nat. Hist. vol. xi. Ehrenberg's Infusoria. Thwaites on Diatomaceæ, in Ann. of Nat. Hist. xx. 9, 343, and 2d ser. i. 161. Smith on Diatomaceæ, Ann. of Nat. Hist. 2d ser. vii. 1.

cell, *d;* and the result is the production of a germinating spore, *s.* In the two lower cells spiral phytozoa are seen. In Hydrodictyon, or Water-net, the cells are so united, as to leave spaces between them, and thus give rise to a net-like appearance.

479. *Rose-coloured Sea-weeds, or Florideæ.*—These Algæ are usually of a rose or purplish colour, and consist of variously-formed cells, arranged either in a single row, or in several rows, so as to form an articulated or an expanded flat and often divided thallus. The organs of reproduction are restricted to particular parts of the thallus, and consist of spore-cases, containing spores, frequently four in number (Fig. 1035), intermixed often with antheridia, or filaments containing spermatozoids, these organs being placed in the interior of conceptacles. The reproductive organs exist either in cavities of the thallus, or in distinct sacs produced on the surface of the thallus, or at the apex of some of its divisions. The occurrence of *tetraspores*, or mother-cells containing four spores, is general in this division of the Algal alliance. The antheridia, according to Decaisne and Thuret, consist of septate filaments, the terminal cell of which assumes a clavate form, and con-

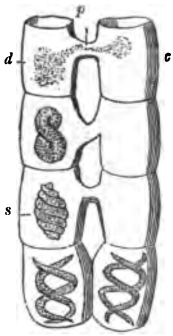

Fig. 1043.

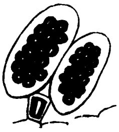

Fig. 1044.

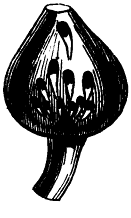

Fig. 1045.

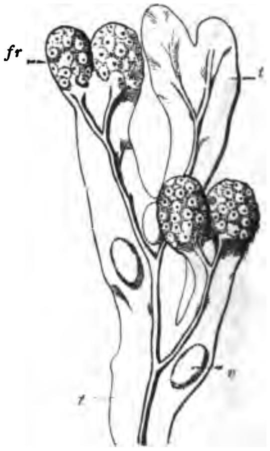

Fig. 1046.

Fig. 1043. Two filaments of a Confervaceous Alga (*Zygnema*), conjugating, *i. e.* uniting together by tubes, *p*, which pass between the different cells. The contents of two cells, *c d*, unite so as to form a germinating spore, *s*. In the lower two cells spiral filaments are seen.

Fig. 1044. Part of the fructification of a rose-coloured Alga (*Callithamnion tetragonum*). There are two sacs called favellæ, containing numerous angular spore-like bodies. These are said to reproduce the plant, and are by many considered as analogous to buds.

Fig. 1045. Part of the fructification of a rose-coloured Sea-weed (*Bonnemaisonia asparagoides*). It consists of an ovate sac called ceramidium, with a terminal pore, and containing a tuft of pear-shaped germinating cells or spores.

Fig. 1046. Thallus, *t t*, of the common Bladder Sea-weed (*Fucus vesiculosus*), showing the fructification, *fr*, at the extremities of the divisions. The fructification consists of a mass of conceptacles united together, so as to form a gleba or large tubercle. In the thallus there are bladders of air, *v*.

tains phytozoa. The latter become free by the dissolution of the walls of the cell. Besides the tetraspores, sacs (coccidia or ceramidia) of a rounded form exist, containing minute spore-like bodies (Figs. 1044 and 1045), which some call sporules. They appear to germinate, and differ from buds, in being contained in special sacs; some consider these cellular bodies as bulbils, which separate from the parent plant; others look upon them as another kind of spore.

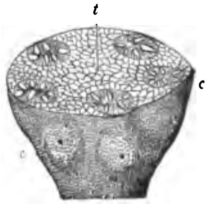

Fig. 1047.

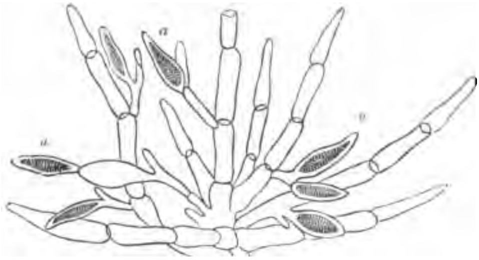

Fig. 1049.

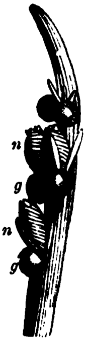

Fig. 1051.

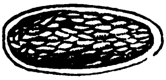

Fig. 1048.

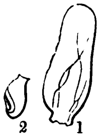

Fig. 1050.

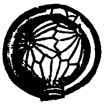

Fig. 1053.

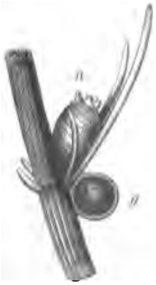

Fig. 1052.

480. *Brown Sea-weeds, or Fucaceæ.*—These are usually brown or olive-coloured plants, growing chiefly in salt water. They consist of cells, which are united so as to form various kinds of thalli. Some-

Fig. 1047. Transverse section of the tubercle of the common Bladder Sea-weed (*Fucus vesiculosus*), showing numerous conceptacles, *c c*, in the midst of cellular tissue, *t*.

Fig. 1048. Antheridium of a Sea-weed (*Fucus serratus*), full of phytozoary cells.

Fig. 1049. Cellular septate filaments, with antheridia, *a a a*, from the conceptacle of a Sea-weed (*Fucus serratus*). The abortive filaments are called paraphyses. The antheridia are sometimes in the same conceptacle with sporiferous sacs; at other times they are in different conceptacles.

Fig. 1050. Antheridium, 1, of a Sea-weed (*Fucus serratus*), containing two phytozoa; 2, a phytozoon, separate, with the two thread-like processes, from either extremity, coiled up.

Fig. 1051. Fructiferous axis of Chara, bearing nucules (spore-cases), *n n*, and globules (antheridia), *g g*, at the points whence branches come off.

Fig. 1052. Axis of Chara, with branches, from the axil of which arises the nucule, *n*, and below the globule, *g*.

Fig. 1053. Globule of Chara, being a rounded body with eight radiating valves externally, and filaments containing phytozoary cells internally.

times the thallus is supported on a distinct stalk, formed of elongated cells; and in the frond there occur also thickened cellular lines, having the appearance of veins. The cells of the thallus are often agglutinated together by a gelatinous intercellular substance. The reproductive organs consist of spore-cases and antheridia, contained in conceptacles (Fig. 1032, *p*), which are aggregated together in receptacles, or large club-shaped expansions, at the extremity or margin of the thallus and its divisions (Figs. 1046 and 1047). The antheridia are sacs (Fig. 1048) borne on jointed filaments (Fig. 1049), and they contain moving phytozoa (Figs. 957, 960, and 1050). The occurrence of antheridia and spore-cases on the same or different plants, has given origin to the terms monoecious and dioecious, which are applied to Sea-weeds by Thuret and Decaisne. When the spores germinate, certain filamentous processes are produced, which burst the outer covering or epispore.

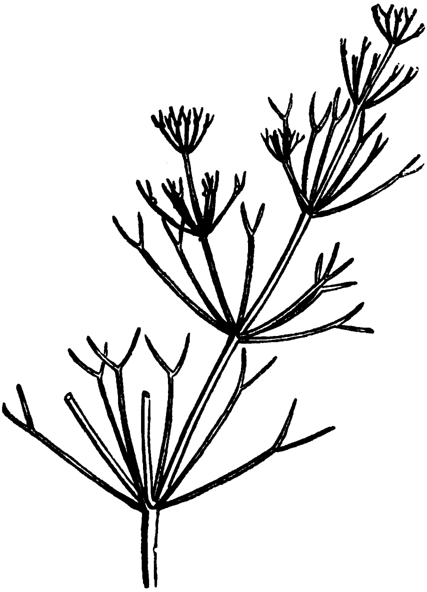

Fig. 1054.

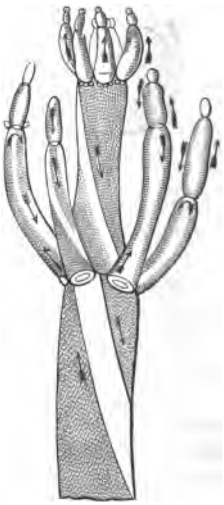

Fig. 1055.

481. *Charas or Characeæ.*—These plants are considered as allied to Algæ, although they present many marked peculiarities. They

Fig. 1054. A species of Chara (*Chara or Nitella flexilis*), consisting of cellular tubes, with verticillate cellular branches, the extremities of which are forked. The plant grows in fresh water, and is referred to the Algal alliance.

Fig. 1055. Part of the axis and branches of Chara, showing, by the arrangement of the arrows, the course of the intra-cellular circulation. There is a regular movement of fluids in the individual cells, as is indicated under the microscope by the motion of granules carried with the current. The subject will be considered under Rotation, or Intra-cellular movements.

consist of an axis formed by elongated tubular cells (Fig. 1054), either transparent, or encrusted with carbonate of lime. From the axis arise branch-like processes, arranged in a verticillate manner. In the interior of the tubes of these plants, distinct circulating motions are seen under the microscope. The currents proceed from one end of the tubular cell to the other, following an elongated spiral direction, and carrying with them granules. This is shown in Figure 1055, and will be specially noticed under PHYSIOLOGY. The reproductive organs of Charas are of two kinds (Fig. 1051, *g* and *n*), one called the *globule* (Fig. 1052, *g*), a spherical body, containing filaments with phytozoa, the other denominated the *nucule* (Fig. 1052, *n*), an oval body, containing a germinating cell or spore.

482. The nucule is produced on the axil of a branch, and consists of a large central cell or spore, surrounded by five cells, which are wound round it in a spiral manner (Figs. 1056 and 1057), and ending in five tooth-like processes at the apex. The spore is contained in a special covering. The globule is usually placed immediately below the nucule (Figs. 1051 and 1052, *g*), and consists of eight valves, enclosing a cavity in which the filamentous articulated phytozoary cells are contained. Each valve is composed of numerous cells, radiating from the centre of the valve, and exhibiting triangular processes at the edge of the valve, by means of which it dovetails into the adjacent valves (Fig. 1053). The cells in the interior of the valvular cavity are filled, like those on the flat portion of the valves, with red granules. On the apex of cells projecting from the centre of each valve, there are numerous filaments (Figs. 1058 and 1060), composed of cells con-

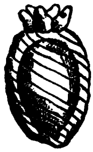
Fig. 1056.

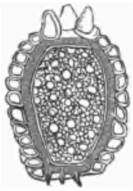
Fig. 1057.

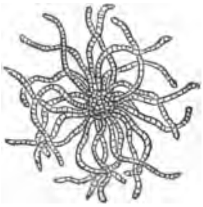
Fig. 1058.

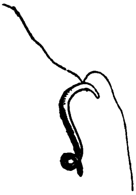
Fig. 1059.

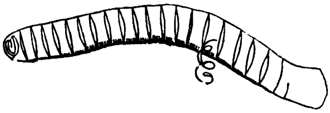
Fig. 1060.

Fig. 1056. Nucule of Chara entire, composed of five cells, wound round a large central cell in a spiral manner, and ending in five processes at the apex, *a*.

Fig. 1057. Nucule or sporangium of Chara cut vertically, showing the large central cell or spore which germinates.

Fig. 1058. Mass of septate filaments, attached to cells projecting from the centre of the valves of the globule. These filaments are composed of phytozoary cells.

Fig. 1059. Phytozoon of Chara, separated from a cell of the filament. Near one of the extremities two vibratile cilia arise.

Fig. 1060. Partitioned filament of Chara, consisting of a series of cellules containing phytozoa, one of which is seen escaping in the form of a spiral thread.

taining minute phytozoa, coiled up in a spiral manner. These escape from the cell, and exhibit spontaneous movements (Fig. 1059).*

483. Brief Recapitulation of the Organs of Cryptogamic Plants :—

1. Some Cryptogamic plants, such as Acrogens, consist of cells and vessels; others, such as Thallogens, consist of cells only. The former may be called Vascular Cryptogams, the latter Cellular Cryptogams.
2. Cryptogamic plants sometimes have conspicuous stems, as seen in the stipes and rhizomes of Ferns. Sometimes they present a flat cellular expansion or thallus as in the case of Lichens; while at other times they have an underground creeping cellular stem, as exhibited in the mycelium or spawn of Fungi.
3. Some Cryptogams have green leaves, with an epidermis and stomata; others are leafless, and are variously coloured.
4. The Organs of Reproduction are in general obscure, and consist usually of cellular sacs of two kinds—one being antheridia, containing phytozoa or spermatozoids, the other being pistillidia or archegonia.
5. In the fully developed state of the plant, the antheridia disappear, while the pistillidia are transformed into cellular sacs of various forms, containing spores.
6. Spores are germinating bodies, considered as formed by a process of reproduction, and as being analogous to cellular embryos. Spores are occasionally furnished with vibratile cilia.
7. Spores are developed in mother-cells, the contents of which often divide into four. Mother-cells, containing two, four, six, eight, or more spores, are called sporidia.
8. Cryptogamic plants are also propagated by buds or gemmæ, which are either attached to the leaves or fronds, or are contained in peculiar cup-shaped bodies.
9. In Ferns, the antheridia and pistillidia are supposed to exist on a pro-thallus or cellular expansion, produced by the spore when it germinates. A cell of the pistillidium (ovular body) afterwards gives rise to the spore-bearing leaves (fronds). The spores are contained in sporangia, with or without an elastic ring, developed on the back, on the side, or at the base of the leaves.
10. In Mosses, the antheridia and pistillidia are seen at certain stages of the plant-growth, and they are either on the same or on different plants. The fully developed fructification consists of spore-cases (sporangia), usually stalked, containing spores which are discharged by an opening either at the apex or side. The apicilar opening is often surrounded by peristomatic processes, which, as regards number, are either four or some multiple of four.
11. In Liverworts, the antheridia and pistillidia are usually on different parts of the plant; and they are frequently in the substance, or on the under surface, of disk-

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* For fuller details relative to the forms and structure of the members of the Algal alliance, consult Agardh, Dissertatio de Metamorphosi Algarum. Vaucher, Histoire des Conferves d'eau douce. Derbes et Solier, sur les Organes reproducteurs des Algues, in Ann. des Science Nat. 3d ser. Bot. xiv. 261. Thuret, Recherches sur les Zoospores des Algues, et des Anthéridies des Cryptogames, in Ann. des Sc. Nat. 3d ser. Bot. xiv. 214; also sur les organes locomoteurs des spores des Algues, in Ann. des Sc. Nat. 2d ser. Bot. xix. 266. Decaisne et Thuret, Recherches sur les Anthéridies et les spores de quelques Fucus, in Ann. des Sc. Nat. 3d ser. Bot. iii. 5. Solier, sur deux Algues Zoosporées, in Ann. des Sc. Nat. Bot. 3d ser. vii. 157. Unger, Recherches sur l'Achlya prolifera, in Ann. des Sc. Nat. 3d ser. Bot. ii. 5. Kutzing, Phycologia generalis, and Tabulæ Phycologicæ. Ralfs, on British Desmidieæ; also in Transactions of Botanical Soc. of Edinburgh, ii. Ralfs, on Diatomaceæ, in Annals of Nat. Hist. xi. 447. Thwaites, on Diatomaceæ, in Annals of Nat. Hist. xx. 9, 343, and 2d ser. i. 161. Smith, on Diatomaceæ. Ann. of Nat. Hist. 2d ser. vii. 1, and on the germination of the spores in Conjugatæ, Ann. Nat. Hist. 2d ser. viii. 480. Decaisne, sur les Corallines, in Ann. des Sc. Nat. 2d ser. xviii. 96. Agardh, sur le genre Chara, Ann. des. Sc. Nat. 1st ser. iv. 61. Amici, observations microscopiques sur le Caulinia fragilis, &c., Ann. des Sc. Nat. 1st ser. ii. 42, and in Ann de Chimie, xiii. 384; sur les metamorphoses et mouvement des corps reproducteurs de divers Conferves, Ann. des Sc. Nat. 1st ser. xiii. 428. Brongniart on Chara, Dict. Classique, iii. 474. Harvey, Phycologia.

shaped cellular stalked expansions. Along with the spores, spiral filaments, called elaters, are seen.

12. In Lichens, the antheridia and pistillidia have not been satisfactorily determined. The fructification consists of thecæ or asci, containing sporidia. There is also an internal green layer of germinating cells called gonidia.
13. In Fungi, the antheridia and pistillidia are obscure. The fructification is various; the spores being either contained in sacs or thecæ (cystidia), or being supported on stalks on the outer surface of cells called basidia. The sporiferous cells are attached to a cellular layer called hymenium, which presents various forms. The hymenium is either naked or enclosed in a cellular membranous covering.
14. In Algæ, antheridia and pistillidia have been detected in many instances, the former being sometimes in the same cavity with the latter, and at other times in different cavities. In some of the Algæ, certain cells, in the same or in separate filaments, seem to possess different properties, and produce spores by a process of conjugation or union. In the lowest Algæ, the cells of the plants divide in a merismatic manner, and produce new individuals.

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